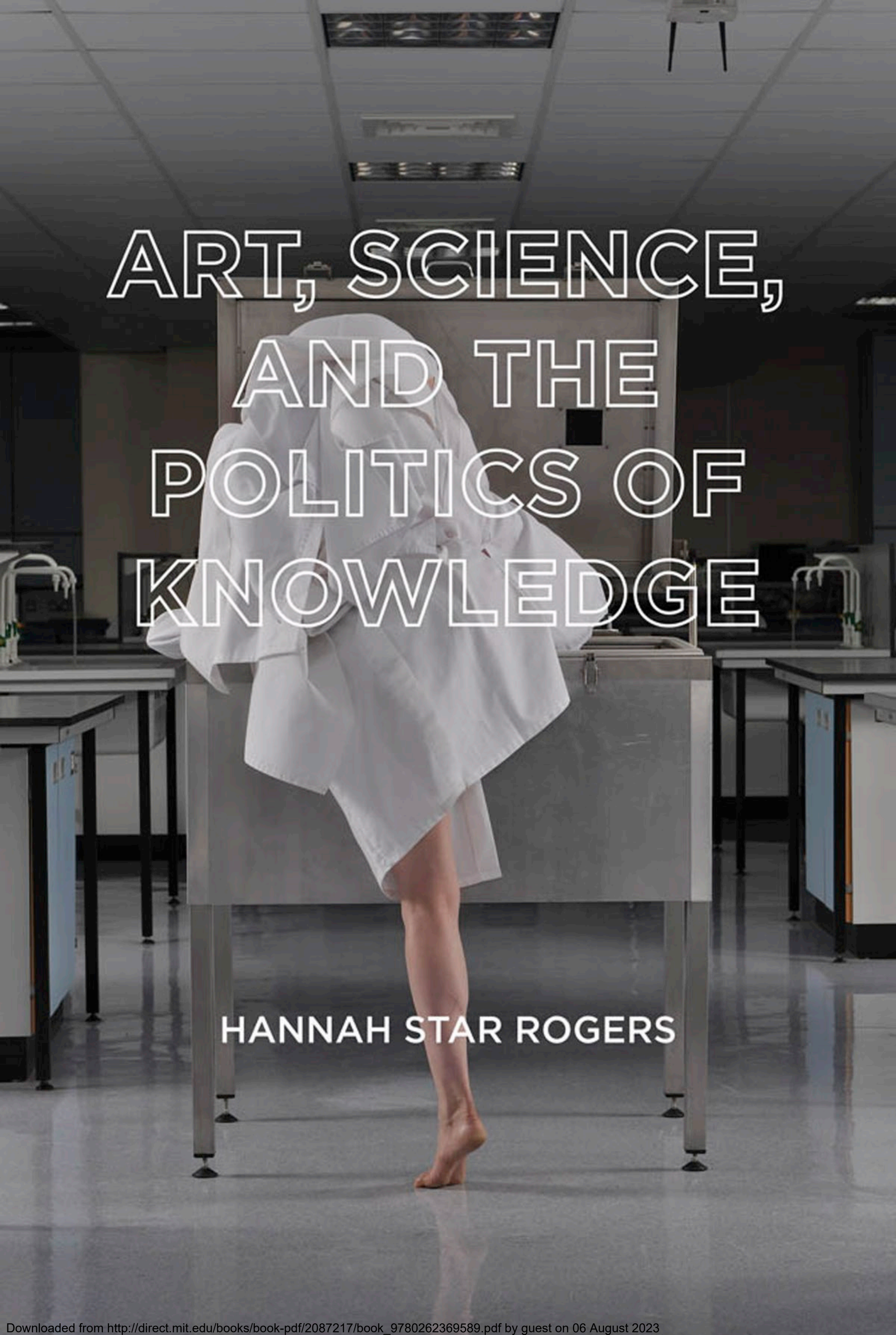

ART, SCIENCE, AND THE POLITICS OF KNOWLEDGE

HANNAH STAR ROGERS

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THE MIT PRESS
CAMBRIDGE, MASSACHUSETTS
LONDON, ENGLAND

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The MIT Press would like to thank the anonymous peer reviewers who provided comments on drafts of this book. The generous work of academic experts is essential for establishing the authority and quality of our publications. We acknowledge with gratitude the contributions of these otherwise uncredited readers.

This book was set in ITC Stone and Avenir by New Best-set Typesetters Ltd.

Library of Congress Cataloging-in-Publication Data

Names: Rogers, Hannah Star, author.
Title: Art, science, and the politics of knowledge / Hannah Star Rogers.
Description: Cambridge, Massachusetts : The MIT Press, [2022] | Includes
bibliographical references and index.
Identifiers: LCCN 2021029454 | ISBN 9780262543682 (paperback)
Subjects: LCSH: Art and science. | Science and the arts. | Science—Methodology. |
Experiential learning.
Classification: LCC N72.S3 R64 2022 | DDC 700.1/05—dc23
LC record available at https://lccn.loc.gov/2021029454

10 9 8 7 6 5 4 3 2 1

This book is dedicated to Hiram Harmon Rogers, Crystal Harmon Rogers, and Hugo Homer Rogers, Jr.

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FOREWORD I

This marvelous book is at once a history of the relationship between science and art and a meditation on its significance. It calls to mind Michel Serres's wonderful work on the Northwest Passage—that ocean route sought for so long as a path between Europe and America that did not have to go the long way around. Serres argued that there was always a passage between the natural sciences and the arts; Rogers takes us convincingly on the journey back.

Drawing especially on the work of Howard Becker, she demonstrates that science and art are similar kinds of human endeavor—they are works produced by elites to reach a specialized public. Under the covers, they are sociologically the same kind of enterprise: "Like art theorists considering what art consists of and science studies scholars querying definitions of science, we might consider the possibility that art and science are best thought of as particular types of attention, rather than features that indelibly mark them as one or the other" (p. 2). As she rightly stresses, the field of science and technology studies has been in the forefront of the sociological and conceptual fusion of the two.

As we go through the volume, we are drawn first to the stunning glass models of sea creatures made by the Blaschkas in the early twentieth century. These may seem from our present perspective to be fabulous curiosities deserving of a cabinet (designed perhaps by Mr. Wilson) of their own; at the time they were invaluable tools for doing marine biology: the transportation and comparison models was much easier than that of biological samples. Later, Berenice Abbott's marvelous freeze frame photographs illustrating some laws of physics would be crucial pedagogical tools—and in turn, the images would themselves capture and constrain as well as feed the imagination of the nascent physicist.

As the volume moves on to tactical media (such as the Yes Men and their glorious hoaxes), we see the nexus of art, politics, and science. The work of Natalie Jeremijenko is perhaps core here—her ecology clinic, barking robot dogs in the Bronx uncovering point sources of pollution and her work on superfund sites of ecological devastation is clearly integrally about art and about science studies' deepest critiques of the nature of the scientific enterprise; as Rogers demonstrates, this is not a nihilist endeavor to attack science, but an attempt to use the tools of science to produce socially rich art. As Rogers argues, "STS scholars should consider how often the very points that we might be inclined to make about the nature of technology or the interaction between technology, expertise, and institutional power are present in artwork." Equally, bioart deploys the tools of the biosciences to unsettle the tunnel vision of many scientists concentrating on just the formal aspects of their work.

Overall, this book eloquently discuss the conjoint development of art and science and especially the rich connections between science studies and critical art. Her clarion call is that attention: "to the construction of art and science and their constitutive areas of knowledge reveals commonalities and frees us from inaccurate divisions so that we may better understand knowledge-making and its accompanying meanings." When C. P. Snow wrote about the two cultures (arts and sciences), he was just wrong—even though we have laid out the architecture of our universities (typically on a north/south divide) as if they were meaningfully distinct. As Bruno Latour (who has done so much to bring together science studies and art) has declared: "We have never been modern"; meaning in this context that the rigid disciplinary and ontological boundaries of the academic enterprise have never been more than shibboleth.

As Rogers demonstrates, science and art share at any one epoch a common toolkit for exploring our sociotechnical/natural world. As a science studies scholar, I have frequently felt that the best work on biodiversity, climate science, biopolitics and the Internet was being performed by artists. Equally, I have felt constrained when writing for leading publications in my field to put artistic work to one side. Rogers's book gives us a much needed pathway for understanding how to weave them together.

This is a timely and vital message: science studies needs to better learn the skills of the artist in bringing critique to a wide audience (we tend to just talk among ourselves); artists need to feel freer to express their art through and with the natural sciences. At stake is our common understanding of the world; and our united efforts to change it.

I warmly commend this work to your attention.

Geoffrey C. Bowker
University of California at Irvine

FOREWORD II

This is a book built around case studies designed to show that the comparison of art and science is no simple task, because "art" and "science" are cultural resources, employed not to describe the boundary between them but to constitute it, and then to keep it constituted—or change it, or destroy it. "Art" and "science" are categories continually being reconstructed by "artists," "scientists," and others with interests in keeping their fields visible and well positioned. As a curator and exhibitor of art works with a leaning toward critical works and living female artists, Hannah Star Rogers has focused on the positioning of contemporary art; and her book has made me aware both of how little I know of it, and how much she knows of science, the main focus of my own work.

The book has also made me aware of Rogers's ongoing effort to coax the "emerging field" of art-STS into existence, and I wish it well, mindful particularly of the relevant context. We currently live in interesting times, with the environment unstable, geopolitics unstable, and outbreaks of internal violence in several developed countries. In the United States and United Kingdom, a move to a Nationalism redolent of Fascism has occurred, and the right is intent on extending and consolidating its power. Its leaders recognize that constituting power is more important than agreeing what (else) to do with it. They deploy power as a generalized capacity to respond to events, but they constitute it by interacting strongly in ever more organized and extended social networks, even as they preach individualism to others. Those minded to oppose them need to imitate them, in order to act collectively as they do. ASTS may be a move in the right direction.

My knowledge of the sciences allows me to make a more confident and better informed response to Rogers's general account of how art and science are collectively constructed. And lest it be thought that my own admiration for what gets done in science is bound to clash with Rogers's discussion of its similarity to the "non-rational" activities of art, I'll immediately make clear that this isn't the case at all. I am a critic of rationalism and admire natural scientists for their patience, not their "rationality." Rogers's case studies are replete with examples that both clarify the meaning of what she is saying and serve as evidence for it. Ignoring minor quibbles, in my judgment her general account is right, and her book should help a range of readers to accept it.

Rogers begins by pointing to Howard Becker's *Art Worlds* as a source of insight into science, and to Thomas Kuhn's *Structure of Scientific Revolutions* as an aid to an understanding of art. Both authors are well chosen for her purposes, but her citation of Becker is particularly apposite. He is widely recognized as a sociologist with an enduring interest in how people do things together, and unlike Kuhn has extended his work into many different contexts and encouraged its wider application. Famous for his studies of deviance, addiction, and music making, as well as art, Becker has also served as a resource and inspiration for studies of medicine, the sciences, and war, all fields wherein artists currently find employment.

Rogers is highly sensitive to the importance of power, whether as a source of support for artists, or of disappointment when they seek genuine respect from it, or as something intrinsically objectionable for them to react against and criticize. Becker, like Rogers, always studies power in specific contexts, but in describing how people who interact with each other can coordinate their actions and thereby do more together he also points the way to a more general understanding of it. Humans may enter the world with powers incarnate in muscles and vocal chords, but they quickly amplify those powers as they interact, share tasks, and fashion tools and artifacts to make them easier to carry out. Today power is vastly amplified in these ways in ever more coordinated societies with extensive division of labor. Musicians, who affect each other from second to second as they sing or play, illustrate what coordination makes possible with wonderfully vivid exemplars; scientific researchers, who make knowledge together and continually convert it from product to resource, provide awesome exemplars of the same thing. In both cases power is amplified by coordination, based on the shared knowledge of a group of interacting human beings. Against this background, Rogers evokes a politics of knowledge wherein artists use art works as carriers of the knowledge they share, and scientists make use of particular exemplary achievements for the same purpose, with knowledges in both contexts changing even as they are routinely used. And her case studies illustrate admirably how the amplified powers latent in these changing knowledges can both increase the provision of collective goods within groups and intensify the conflicts between them.

There is still no general agreement that knowledge is collectively constructed, and the facile rhetoric of individualism still runs rampant in our culture, at the end of my own career as at the beginning. But much has changed over that time notwithstanding, including how people think of power and their relationship with it. Rogers notes how the power that artists currently relate to is largely financial: artists struggle for resources made available as sums of money. And the form of money is itself changing rapidly, as politicians require banks to create it electronically in unprecedented quantities. It is hard not to notice today that money is fiat money, valuable not because of what it is made of but because of how it is treated. Money is whatever has that status, and that status has to be constructed collectively just as all statuses are, including science and art and other institutionalized fields of activity. Rogers may always hope to convince, or confound, any who remain skeptical of her general argument by pointing to this ubiquitous and well-known exemplar of something collectively constructed, and continually being reconstructed.

Barry Barnes

PREFACE: THE RISE OF ART-SCIENCE

Seeking to understand the categories of art and science as labels with specific powers to order social worlds allows us to recognize the similarities and overlapping practices of these knowledge communities. There are many contexts in which this switch might be a fruitful approach to considering the constructed nature of knowledge systems. What happens when we encounter the word "art" in daily life or scholarship and replace it with "science" in our minds? In these quotes from Howard Becker's *Art Worlds* (1982), the word art has been replaced with science (my italics): "*Science* worlds consist of all the people whose activities are necessary to the production of the characteristic works which that world, and perhaps others as well, define as *science*" (34). The principle Becker puts forward here is immediately recognizable to science and technology studies (STS) scholars as ideas they apply when thinking about science as it is defined by its actors and their work, rather than an external philosophy of science. Continuing in this vein, Becker's remarks about art resemble STS ideas about science in relation to the subject of state control: "Like other participants in the making of *science* works, the state and its agents act in pursuit of their own interests, which may or may not coincide with those of the *scientists* making the works . . . the state pursues these interests both by supporting what it approves and by discouraging or forbidding what it disapproves . . . by intervening in the production of *science* it considers inimical to its interest" (165–167). This suggests that there may be many works that have been written with art in mind that might inspire the STS scholar to look for similar patterns in science.

Related discoveries may ensue from examining STS work's potential applications in art. Here, *science* is replaced with "art" [my italics] throughout the following quotes from Thomas Kuhn's foundational *The Structure of Scientific Revolutions* (1962): "That element of arbitrariness does not, however, indicate that any *artistic* community could practice its trade without some set of received beliefs" (4). Many of Kuhn's ideas function well in describing assumptions in art. They are also helpful in considering the transition between art movements: "The successive transition from one paradigm to another via revolution is the usual developmental pattern of mature *art"* (12) and "Men whose research is based on shared paradigms are committed to the same rules and standards for *artistic* practice" (11). Transposing art and science and vice versa reveals that many ideas developed to consider art might be recognizable in STS as applying to science or may usefully extend our understanding of science . This is not to suggest that art and science are interchangeable or identical but rather to suggest that if STS seeks to understand the character of knowledge production, we should be eager to seek out similarities as well as differences. Particularly given the extent to which STS has pointed out differences among sciences, we should be equally eager to see the differences and similarities across the sciences and the arts, which are themselves philosophically and practically diverse. We should also be interested in all the actors involved in these knowledge networks, which may include some people, objects, and ideas that are usually associated with the other network. Analysists of both art and science have faced this definitional inclusion problem.

To be this point, Becker grappled with the problem of who makes up the art world, the same problem encountered by STS scholars considering who to include as part of the scientific enterprise. Likewise, Becker's second quote is familiar to STS scholars, who have learned to think of marginalized science not as a failure of a truth claim but rather as an issue of social marginalization (Collins and Pinch 1998). Indeed, Becker's concept of "worlds" was employed in relation to the sciences by scholars such as Elihu Gerson (1983), Adele Clarke (1998), Susan Leigh Star (1995), Geoffrey Bowker and Susan Leigh Star (1999), and Joan Fujimura (1996). Becker's art worlds are networks in which materials and people associated with art objects circulate. Galleries, studios, and museums are populated by multitudes of artists, curators, critics, patrons, and art-going members of the public who encounter materials and rhetoric. They collectively engage in labeling things as art and nonart to varied effects.

Similarly, many statements that STS scholars have made might well apply to art communities and practices of knowing. Kuhn's explanation of scientific "progress" through paradigm shifts can be applied to art, where periods of sustained and aesthetically similar art-making inside and among various schools and sub-disciplines are interrupted by sometimes extreme changes in form and content. This linguistic reversal offers a role reversal that reveals the thicket of indeterminacy from which the social power of categories makes order. A comparison of Kuhn and Becker's studies of their respective knowledge communities reveals that it is social processes, not universal attributes, that divide art and science.

STS has shown that the idea that scientists work with things, while artists work with representations, is not accurate: scientists spend their time working on representations too. Both scientists and artists are often engaged with representative means: they tell us something using something else. Often this takes the form of a narrative in which language is replaced with things to make an argument that is legitimized by material instantiation. As STS scholars, we might do well to think about why those arguments are effective for putting forward an agenda that separates the categories of art and science or that holds the two together. Both are constructions that require effort to maintain. In her plenary address to the Society for Literature Science and the Arts in 2011, philosopher Isabelle Stengers described the pressure on the "non-rational" world from the "rational" world as continuing to grow. She proposed that modernity has become associated with various forms of scientific rationality. Stengers distinguished between various scientific subjects and suggested that in the current way of categorizing knowledge, the non-rational is relegated to a non-civilized status. Because science is a constructive enterprise, a highly contingent system that does not simply discover preexisting truths but, through specific practices and processes, helps shape them, the non-rational is seen as inefficient and irrelevant, instead of offering values that in times past would have signaled taste and sensibility. Stengers was particularly concerned that an embrace of the "rational" may signal the invalidation of other discourses.

Science communities have held that to participate in proceedings and discussions, a participant must use the community's standards, thus rendering moot any attempt by artists (or other outsiders) to comment from a non-science perspective. This could be said for those wishing to contribute to artist communities too. By taking up the materials and subjects of scientists, many artists have been able to cloak their work in the signs of science and participate in or comment on the community in ways that look much like science that has already been deemed legitimate. On closer examination, scientists themselves or the public may reject these claims, but a surface of signs creates a temporary opening for non-scientists to discuss science-related subjects.

Because of art's resistance to science's attempts to subsume and colonize other forms of knowledge, art has special value to STS as an exemplar, an area full of objects and practices for examination, and a new set of methods. Art is proving the basis for a new subdiscipline called Art, Science, and Technology Studies, complete with new kinds of STS practitioners. These include curators and facilitators, who use a distinct methodology drawn from the STS canon and share many of the same philosophical principles and tradition of critical inquiry but with substantially different material practices and ways of reaching beyond the academy into a plurality of publics. ASTS methodology and conceptual toolkit enable a way of knowing science and art that should be recognized by STS and developed as another way to examine knowledge-making practices.

Art's refusal to accept science's hegemony makes it a worthy object of study. Early science studies took aim at physics because of its powerful standing in the social world. This standing was partly based on the idea that laboratory practice was the heart of science and that it was a particularly "rational" theoretical and experimental practice. STS tools have been employed to examine the production and standing of non-science knowledge and the same tools that have been used to explore conceptions of rationality has been and continues to be employed in the study of that supposed bastion of the non-rational: art. The subjective could return as a viable site of knowing, given the correct social conditions.

In contributing to and exploring what science is, without an attempt to situate their work as the only potential viewpoint, these artists have the capacity to introduce the public to the subjectivity of science issues in a productive way.

It is often suggested that in the past thirty or so years, a distinct set of social relations and practices have emerged at the intersection of the worlds of art and science. This expansion of work considered to be at the intersection of these two knowledge areas gives occasional reflection on the categories of art and science and their longer histories. As even a cursory read of media coverage, museum documentation, and the web pages of interdisciplinary university programs shows, there is rising interest in the phenomenon of art-science, which takes several forms. Some art-science projects are intended to engage the broader public on pressing issues from science and public policy perspectives. Exhibits of art-science are proliferating, especially around such themes as genetics, biotechnology, and climate change.[1] Other art-science ventures focus on bringing disparate groups of experts together. Such efforts have attracted prestigious institutional support, including from the National Science Foundation (grants for Exploring Science in the Studio), the Swiss international exchange program Artists-in-Labs, and The University of California, Los Angeles Art/Sci Center. Still other artist-run initiatives operate as art-science collectives, often embedded in existing institutions, such as the University of Buffalo's Coalesce: Center for Biological Arts and the University of Western Australia's SymbioticA, both of which have complete biological laboratory facilities. Also increasingly prevalent are public participation/citizen science communities centered on community spaces for digital interventions, biohacking, and do-it-yourself biology. Such initiatives are often led by artist-scientist teams, opening laboratory spaces to users who would not otherwise be able to access laboratory space in universities or corporate spaces. Community laboratories have been organized in many cities, including Genspace in Brooklyn, MadLab in Manchester, England, and ASCUS Art & Science in Edinburgh, Scotland.[2]

Other organizations with longer histories of involvement in art-science have been rejuvenated by the upsurge in art and science activity. Founded in 1968, Leonardo/ISAST (International Society for the Arts, Sciences, and Technology) is today a major hub for such activities.[3] The Ars

Electronica festival, begun in 1979, currently hosts the foremost prize for art, technology, and society. In 2016, Leonardo/ISAST and the National Academies of Science launched the first full-scale study of the effects of teaching art and design methods to science students. Sponsored by the Cultural Programs of the National Academy of Sciences (CPNAS) in collaboration with the National Academy of Engineering; Leonardo/The International Society for the Arts, Sciences, and Technology; the journal *Issues in Science and Technology*; and The Alliance for the Arts in Research Universities (a2ru), the wide-ranging report attempted to assess and survey the results of art education on science and engineering student outcomes.[4] Such public policy initiatives encourage the move from STEM to STEAM and the hope that interdisciplinarity will have positive social, environmental, and economic effects.

Most art-science efforts have less focused outcomes, however. American funding bodies have been especially eager to develop standards to measure success. But such efforts present serious complications in terms of documentation and evaluation and have yielded inconclusive results to date. Capturing one-time data or learning about the effects of single and multiple informal science encounters is fraught with complications even as the number of such opportunities for understanding audiences' relationship to art and science works proliferate (Casini 2010; Born and Barry 2010; Barry, Born, and Weszkalnys 2008; de Ridder-Vignone 2013). It is not clear that stable or even coherent definitions of art and science are being used across these projects, and relatively little research has been done to understand how such work could come to belong to both knowledge systems.[5] To be sure, STS scholars have long worked to expand ideas about what science is and can be, effectively opening it as a field from which to draw subjects and methods and presenting a new set of institutions and practices to critique.

Similarly, across a similar time frame, artists began to contend that all techniques are appropriate to art, and even to assert that any object can be art, as in Marcel Duchamp's readymades. The concept of "relational aesthetics" developed by art historian Nicolas Bourriaud (1998) applies here, because many artists consider any human interaction and social context as a potential mode of art-making. This concept further radicalized the notion that "everything" is art. Hannah (2013) has argued that this idea makes it possible to imagine scientific experiments as art and to open the spaces of science to "performative experiments" by artists. It is easy to imagine how these moments of art in social relations become further complicated in the context of the experiment as a form of argument or persuasion rather than the dispassionate unveiling of objective truths (Pinch 1993). If scientists perform in public and stage demonstrations for political purposes (the acceptance or rejection of a new technology, for example), their ability to coherently separate their aims and means from those of artists who work in this area remains an open question.

At the same time, other scholars have suggested potential limitations of the knowledge system art puts forth. Nora S. Vaage (2020) engages the concerns of scholars working in artistic research with the connotations of the word "knowledge" in this context. She cites Kathrin Busch (2009) and Hito Steyerl (2010) in considering the fear that the use of this term may reduce art to science communication or implicate it in capitalist structures, which much contemporary art seeks to critique. Vaage suggests that the word *wisdom* be used in place of *knowledge*. Such concerns about reductive understandings are real and yet they are highly contextualized. This interpretation relies on shared reference points in our current context, in which resources for actors' projects are bound up in specific understandings of what art is or ought to be in relation to science. They do not object to the idea that art and artistic experience constitute a form of knowledge. Steyerl's emphasis on tacit knowledge suggests one type of shared relationship; their objection is how these definitional associations might lead to limitations in artmaking and interpretation. Furthermore, the idea that a set of standards for knowledge production in science and technoscience exists at all is contested. Different areas hold different views of the most epistemically valued forms of verifiable and reliable knowledge conception and of their proper types of inquiry (Graham 1993).

Given this, I do not fear that art's fragmentary and diverse ways of recognizing knowledge will be subsumed by science's fragmentary and diverse ways of recognizing knowledge. Rather, the identification of current power relationships can help us to contextualize ongoing art-science relationships and recognize similarities in their respective operations. These questions are best addressed by considering the power relations between art and science in context; the issues raised by these scholars relate to the way in which the standards of knowledge production from science might be wielded against art producers today and are not related to art's own forms of knowledge certification. As STS scholars have worked to enlarge the communities that are recognized as knowledge-producing entities in their home discipline and beyond, art is certainly ripe for analysis as a community of comparison.

With the rise in art-science work, the need for critical analysis of these developments has become increasingly clear. What is required is a new interdisciplinary field capable of fully theorizing this area, one that recognizes artists as contributors to the scientific project, advances new methods of work, and renews the STS commitment to analyze all forms of knowledge. The development of art-focused STS, or Art, Science and Technology Studies (ASTS), is a response to this demand. With roots in STS and critical theory, ASTS applies hybrid tools to investigating art-science collaborations and instances where art or science interact and intersect with each other. As articulated in the Routledge Handbook of Art Science and Technology Studies, ASTS draws on methods and concepts derived from STS, treating art symmetrically with science in analyzing both art and science as constructions of human knowledge-making (Rogers et al. 2021). The various methods used by scholars featured in that book include ethnographic studies, historical cases, and reflective pieces by art-science teams. Work positioned as both art and science requires a commensurate shift in our analytical and conceptual equipage. Gains that are possible by bringing a fuller understanding of the constructed nature of knowledge categories to bear on work may initially seem to slot easily into an art or a science camp. As an act of questioning in this tradition, this book does not take for granted the separateness of art and science. Art and science have interesting things to tell us about the ways in which we construct differences in types of knowledge. Rather than portraying a moment of divergence or border-building between science and art in the manner of Thomas Gieryn (1983) or relating to art and science through concepts like objectivity (Daston and Galison 2007), this book explores cases that complicate conceptions of art and science.

The range of relationships explored in the cases presented show how art and science dynamics resulted in changes in the ways that actors perceived the two categories, provoking critical reflection of the value that people assign to them. An examination of these orientations offers opportunities to think about ways to avoid naturalizing the role of scientists or artists. The work to produce these categories involves the deployment of rhetorical strategies by experts and critics, in addition to artists and scientists. Together, these actors construct an apparatus for labeling objects, people, and stories, one so ubiquitous that it acts on both the knowledgeable and the less knowledgeable within the categories, as well as on lay observers and those participating in the other respective network.

Of course, the art-science boundary can be and is often contested and the ways the concept is expressed art-science versus SciArt or ArtSci carry particular meanings inside and outside of its related communities.* For many of the actors I investigate, that boundary is a chasm, created to be overcome by those who are able to utilize this system of categorization for their own purposes. Art is sometimes treated monolithically, much like science was spoken of before STS revealed diversity of paradigm, proof, and experimental style. Art, too, is endlessly diverse and protean, further complicating the idea of a liminal object moving between two poles. There is no single transition or traceable change in how objects fit the many definitions of art and science. Instead, the two categories are constantly in flux, with the potential to be employed by actors for specific purposes around specific objects.

A key goal of this book, accordingly, is to map the range of relationships encompassed by art and science and show how they shape art-science labeling. In this manner, this book casts into relief the dynamics that govern actors' perceptions of the two categories, provoking critical reflection of the value that people assign to them. This reorientation of the power of artists and scientists is neither progressive nor linear. Each of these modes of power between artists and scientists is persistent, and an examination of these orientations offers opportunities to think about ways to avoid naturalizing the role of actors via prescribed categories.

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*SciArt is often understood to be science-driven artworks while ArtSci is often understood to refer to art-driven projects which are about science. Art-science is hardly a neutral term since it tends to suggest a pathway of collaboration between artists and scientists, while "art and science" is easily confused as suggesting a separation between the two. There are, of course, many nuances to this debate, but suffice it to say that I have chosen art-science to refer to these practices in the preface because I hope to suggest the similarities between the practices of these groups rather than art in the service of science or art influenced by science.

The division of art and science is reinforced by signs deployed by the respective communities, the ways of talking about and seeing work that reference the terms of the other group. Swiss linguist Ferdinand de Saussure's response to the everyday notion of language as nomenclature is instructive here. As Ian Hacking noted in interpreting Saussure (1983), language does not simply provide the ability to name pre-existing categories. It also creates new categories for thinking, rather than standing in for things in the world. In assuming that language describes predetermined categories, non-linguists "repress the reciprocal determination of values in the language system which arises from their very co-existence." The limits of linguistic conventions are well known in studies of race, class, and gender. Like binary gender labeling, where only two available designations are commonly assigned to everything from language to objects, objects are typically assigned either an art or science valence.

Similarly, objects, people, and even certain ways of framing stories that appear in the cases in this book are frequently described by the actors I researched as either art or science. The affinities between the treatment of art and science and their relative gendering continues to create complications in the way in which the two areas are valued. Once the roles artists play in relationship to science is understood, we can see and appreciate them in the company of other marginalized and long-ignored groups that STS has helped to bring into the historical record. Artists, too, have contributed to scientific knowledge, in ways hitherto dimensioned by our understanding of their work as auxiliary, at best, in the knowledge-making enterprise.

The stereotype of bipolar science and art mirrors some historical modes of understanding gender. In the western context, particularly since the early modern period, the two genders were seen as opposites in a complementary fashion that created a "complete" household. This process was transferred into science and art, which have typically been depicted as distinct yet harmonious spheres when in each other's company. Good science is often masculinized, described as rigorous, logical, and is best performed by those with an "objective" temperament, usually meaning not only men but also men of admirable masculine character. The "hard" sciences were long assumed to be superior.

Art, on the other hand, has often been accorded the passive role of muse for science with *emotion* and *subjectivity* as its watchwords. Rarely has art been seen as a direct contributor to scientific enterprise. The work of feminists is central to this book in two senses: first, in deconstructing binaries and in identifying the way in which sex in dimorphism has been used as a metaphor in contexts otherwise unrelated to sex; and second, in recovering contributions rendered invisible by bias. Just as the gender segregation outlined here has begun to be broken down, the potential exists for the separation between the arts and sciences to be deconstructed.

Understanding the relationship that is being configured, either through documents that explain a story of ideas and objects or by encounters with the object itself, requires a type of attention that matches the story being told. The attention commanded by art versus science has been crafted differently by different sets of actors. For example, we understand that a newspaper demands a different sort of attentive attitude than a poem, yet both require some of the same skills to read. Like art theorists considering what art consists of and science studies scholars querying definitions of science, we might consider the possibility that art and science are best thought of as particular types of attention, rather than features that indelibly mark them as one or the other.

The ideas and information that we extract from a sculpture or data chart depends both on our identification of the object with a category and on our trained interpretive power. In the latter sense, questions about the identity of people and objects are brought forward. Understanding an object or person in terms of an art or science network positions the object of analysis for comparing and contrasting to others of its type. Hence, reflecting on the type of attention we pay based on our identification of the relevant knowledge network can reveal ideas about what the category involves and the relationship that we perceive between form and content.

One place to look at the relationship between form and content is the way in which art and science align materials and argue for their meaning and rhetoric. In both art and science, this material-rhetorical complex is frequently referred to as *experiment*. Like the designs of technologies that argue for particular worldviews, experiments, too, propose worlds by organizing materials that stand in for things not present. In short, ideas are represented through materials. Sometimes, materials are the same in kind as the counterparts that they are meant to represent. At other times, they are figuratively or analogously represented. Deconstructing experimentation and its contexts to understand how empirical systems are socially valued was the focus of much early STS work, notably by Bruno Latour and Steve Woolgar and by Steven Shapin and Simon Shaffer. The practices of science align materials to make arguments about general principles; they reach for ideas using objects rather than texts.

Hence, the practices of art and science have much in common, in the way objects are forged to meet their respective standards and how the actors perceive the categories and their potential uses through the logics and norms of each pursuit. Rhetoric and objects and the people who use them become both signs of the category and the thing—art or science—itself.

ACKNOWLEDGMENTS

The development of this book roughly parallels the growth of a group of scholars, artists, and scientists who make up the Art, Science, and Technology Studies community. I am deeply grateful to my Art and STS reading group and co-editors of the *Routledge Handbook of Art, Science, and Technology Studies* Megan K. Halpern, Delilah Hannah, and Kathryn de Ridder-Vignone for their contributions to this emerging field and friendship. Equally important are the panelists who joined me at the Society for Social Studies of Science (4S) and the Society for Literature, Science, and the Arts (SLSA) meetings for conversations about the emerging field of ASTS. I am also thankful for the support of Jane Calvert and my peers at the University of Edinburgh's Science, Technology, and Innovation Studies department. I am very grateful for the extensive and helpful ideas of Matthew N. Eisler, who helped to bring this text to its final form and who has supported my art-science exhibitions from proof reading wall text to cleaning gallery space.

My interest in art and science began at Duke University in Jim Applewhite's advanced undergraduate course on aesthetics and science, with a note I scrawled in the margin of Wordsworth and Coleridge's *Lyrical Ballads* about what the concept of the "experiment" meant in poetry versus in science. This question led me to graduate school in STS at Cornell University, an environment where I was able to nurture my research subjects. I acknowledge the extensive support of Phoebe Sengers, Michael Lynch, Trevor Pinch, and above all, my mentor and friend Judith Reppy, whose steadfast interest and insights brought me through many stages of research and whose feedback on so many drafts made this book possible. Thank you also to E.J. Neafsey for editorial support and kind help through my dissertation writing. I also relied on the encouragement of Steve Hilgartner, Bruce Lewenstein, Honghong Tinn, Darla Thompson, Marjorie Levinson, and my cohort at the School of Criticism and Theory, as well as Charles Cording, Russell Williams, Ming-cha Liu, Jean Basinger, Shalonda Green, Mary Stevens, and Alice Major.

I have been extremely fortunate to be able to document the emergence of new work in art and science. I am indebted to my early interviewees, including Oron Catts, Ionat Zurr, Tarsh Bates, Brooke Singers, Adam Zaretsky, Natalie Jeremijenko, Joe Davis, Stelarc, Daisy Ginsberg, Paul Vanouse, and Kathy High. Research for this book was supported by the National Science Foundation, the Society for the Humanities, and the Eindaudi Center for International Studies. This book was partly composed at several excellent residencies including the Akademie Schloss Solitude Fellowship in Stuttgart, Germany, the Jerome Foundation-sponsored emerging artist residency at Tofte Lake Center in Ely, Minnesota, the Djerassi Artist Residency in Woodside, California, and Field_Notes in northern Finland (my appreciation to Erich Berger). I was able to make important progress on the manuscript thanks to timely postdoctoral fellowships from the Center for Nanotechnology and Society at Arizona State University and the Bard Graduate Center in New York. While attending Columbia University for my MFA, I further developed the book and benefited from conversations with Timothy Donnelly and Pamela Smith. I also owe thanks to Genspace founder and Biodesign Challenge Director Dan Gruskin for vigorous conversations around the subjects in this book. I am also grateful to the teams of STS scholars, artists, and gallery professionals with whom I worked, and had wonderful conversations, in curating *Making Science Visible: The Photography of Berenice Abbott* (2013), Arizona State University's *Emerge: Artists and Scientists Redesign the Future (2016 and 2017),* and *Art's Work in the Age of Biotechnology* (2019–2020 and 2021), particularly Worthy Martin, Dave Guston, Molly Renda, Fred Gould, Todd Kuiken, Roger Manley, Mary Hauser, and Elizabeth Pitts.

Thank you to my MIT editor Katie Helke and her team, including Barbara Chernow, Linda Van Pelt, and Laura Keeler. Thank you to Lisa Parker at the University of Pittsburgh for supporting STS and art research and the color images for this book. I also thank my Sense of Place course collaborator Director Jim Costa of Highlands Biological Station and Bernie Carlson at the University of Virginia for giving me the latitude to develop STS courses on art and design with my dear friend, the environmental scientist Art Schwarzschild, who sadly passed away in 2016.

I am eternal grateful for the help and love of my brother Hiram Harmon Rogers who is my first reader, personal librarian, and a constructive conversationalist no matter what subject I am researching. Finally, I thank my parents and extended family in Alabama for their ceaseless clippings about art and science and their enduring love. Thank you.

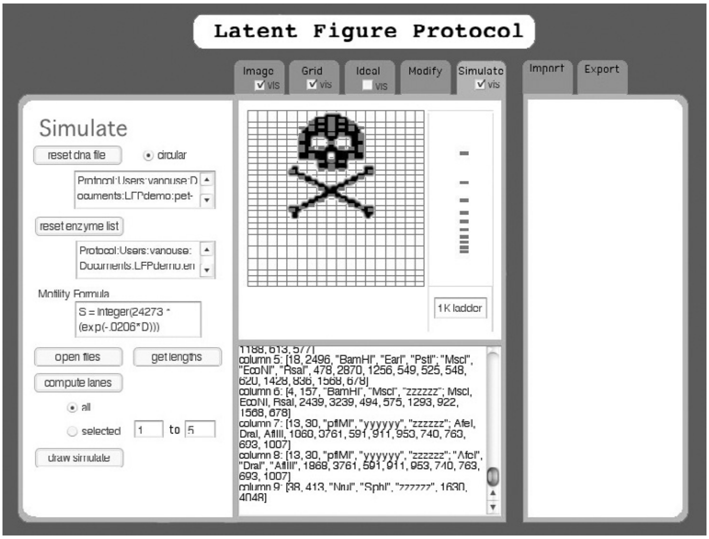
1

INTRODUCTION: ART IN SCIENCE AND TECHNOLOGY STUDIES

A man in dark clothing leans over a pile of plastic pipette ends, carefully squeezing the contents of one into a gel electrophoresis tray. Adjusting his lapel microphone, the man says that he will now manipulate the trays to create a series of predetermined images, beginning with a copyright symbol (figure 1.1). Before him, in a darkened gallery, an audience stirs. This is no science laboratory, at least as such facilities are conventionally understood. It is an art gallery, and the man in the white lab coat is engaged in a performance he calls *Latent Figure Protocol*. He explains that his work illuminates how gel electrophoresis operates and critiques our assumption that a sample can be called a DNA "fingerprint."

This is the work of Paul Vanouse (2007). But is it art or science, and at what point can or should the two be separated? And what does it mean to use these categories? In both art and science, the importance of the public and the politics of contemporary science are close at hand. In Vanouse's classic performance, viewers encounter the reverse engineering of DNA fingerprinting. Using known enzymes to cut specific lengths of DNA calculated using software he has created (Figure1.2), the artist is able to display a pictorial image of a "1" or a "0" or, for that matter, any image he chooses. In this way, the artist inverts the political aims of DNA fingerprinting and draws out new interpretations of this scientific image-making technology (Figure 1.3).

1.1 Paul Vanouse, *Latent Figure Protocol*, installation. *Source*: Photograph by Axel Heise. Transmediale Festival, Berlin, 2011.


Latent Figure Protocol
Image ☑ vis
Grid ☑ vis
Ideal ☐ vis
Modify
Simulate ☑ vis
Import
Export
Simulate
reset dna file
● circular
reset enzyme list
open files
get lengths
compute lanes
● all
○ selected
to
draw simulate
1K ladder

Protocol:Users:vanouse:Documents:LFPdemo:pet-

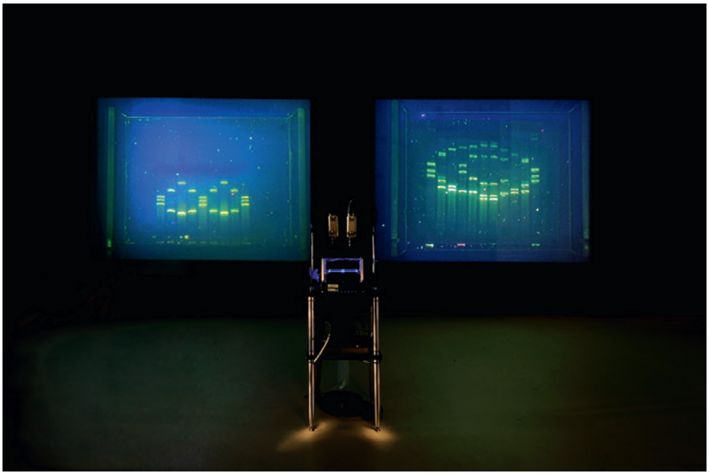
Protocol:Users:vanouse:Documents:LFPdemo:en

Motility Formula: S = Integer(24273 * (exp(-.0206*D)))

selected: 1 to 5

```
1188, 613, 577]
column 5: [18, 2496, "BamHI", "EarI", "PstI"; "MscI",
"EcoNI", "RsaI", 478, 2870, 1256, 549, 525, 548,
620, 1428, 836, 1568, 678]
column 6: [4, 157, "BamHI", "MscI", "zzzzzz"; MscI,
EcoNI, RsaI, 2439, 3239, 494, 575, 1293, 922,
1568, 678]
column 7: [13, 30, "pflMI", "yyyyyy", "zzzzzz"; AfeI,
DraI, AflIII, 1060, 3761, 591, 911, 953, 740, 763,
693, 1007]
column 8: [13, 30, "pflMI", "yyyyyy", "zzzzzz"; "AfeI",
"DraI", "AflIII", 1868, 3761, 591, 911, 953, 740, 763,
693, 1007]
column 9: [38, 413, "NruI", "SphI", "zzzzzz", 1630,
4048]
```

1.2 Paul Vanouse, *Latent Figure Protocol. Source*: bespoke software written by Paul Vanouse, Macromind Director, 2006.



1.3 Paul Vanouse, *Latent Figure Protocol*, performance. *Source*: Photograph by David Familian, University of California Regents. Beall Center for Art + Technology, Irvine CA, 2013.

Vanouse trained as an artist rather than as a biologist or science communicator, and his work is displayed in art galleries. On their own, however, actors' categories or community norms may not be enough to decide whether a work is art or science. These categories are rhetorically shaped and operationalized, used to circumscribe bodies of knowledge, demarcate resources, delineate interests, and separate social groups. Practitioners engaging in rhetorical positioning make and unmake meanings, fitting objects into knowledge networks of art, science, or combinations of both.

Categories of art and science have important implications for how knowledge is valued that correspond to the relative power of art and science in our society. Enriching understanding of these categories can recover the important contributions of artists to past scientific enterprises, contextualize current art-science movements, and anticipate their future potential. Conversely, conceiving art and science as distinct knowledge-making enterprises can disrupt the relative power assigned to these areas in scholarly and public spheres.

Let us consider these two worlds, their similarities and differences. We conventionally treat art and science as necessarily separated even though these categories do not form a natural or even coherent split between materials or philosophies. Close readings of projects of science and art readily reveal overlaps. For different practitioners and audiences, what counts as art or science, and their associations, varies in interesting ways. Some argue that a third culture has emerged in the last thirty years or so as more art-science ventures have been created. Others assert that such a culture is not possible because the existing standards of both art and science are crucial to these emerging practices (Halpern 2014).

Yet there is a complex and unstable lineage of people and practices identified as both art and science. As constructed categories, art and science have coexisted much longer than the newly recognized movement of art-science suggests (Salter 2010).[1] Despite being neither natural nor stable in relation to people, objects, or practices, these categories do useful work in obtaining results sought by practitioners. It is this instability that underpinned the interest of STS in practices of categorization as means of readily illustrating the social nature of knowledge production. Such approaches were anticipated by an earlier generation of scholars, such as the sociologist Harold Garfinkel (1967), whose social "breaching experiments" involved researchers engaging in unexpected behaviors designed to trigger interactions. Sociologists Susan Leigh Star and Geoffrey Bowker further developed methods of problematizing categorization (1999). In a similar vein but with a different target, feminist scholars like Judith Butler (1990) made clear the importance of supposed anomalies in understanding the rules of gendering.

Bowker and Star's *Sorting Things Out* (1999) offered a fully-fledged explanation of the power wielded by systems of classification. Classification makes possible, but also removes from circulation certain meanings. In the case of art and science, this has involved making those designations more exclusive. When something is labeled as science, it becomes more difficult to see in it the qualities of art, and vice versa. Those additional meanings are to some degree removed from consideration by the presence of the classification. How the elements of art and science categories are classified influence and sometimes constrain possible uses in the other category. As we will see in the case of the bioarts, sometimes the tint of power left by the object's association with science is precisely what the artists aim to address in their pieces. For example, the use by artists of tissue culture techniques that require specialized equipment, such as bioreactors installed in the gallery space draws attention to the fragility and specific needs of the life being housed in it, while creating room to redirect the scientific machine's power for the artist's purposes.

The availability of these two handy classifications causes some people to see the split as applicable everywhere, and yet either label defers the thing itself. Like "hands" being used to describe workers or "the crown" standing for the Queen, elements from either network can come to stand in for the whole. References to the Mona Lisa and microscopes conjure many associated ideas when they are mapped as fitting exclusively into the categories of "art" and "science." These stabilized clusters make it possible for bioartists to use white coats to signal scientific power without needing to establish a connection between lab coats and themselves or their work. Similarly, simply hanging scientific images in an art gallery without changing the image from what would be seen in a scientific article can cause the image to be re-read and produce entirely different meanings. The categories defy easy definitions that do not capture the porosity of the boundaries. Instead, art and science are representationally understood through signs or example objects (white coats, gallery spaces) meant to explain the whole: synecdoche substituting for the indefinable.

In the past decade, a host of art-science projects have attempted to bridge the supposed gulf between these areas of knowledge. Some of the most interesting such work tends to naturalize the differences between the two areas and then celebrate moments of communication, overlaps in practices, and mutually useful outputs. One explanation for this approach is that much of the work at the intersection of art and science rests on assumptions that do not account for ideas about the social construction of science. In such work, science tends to be seen as verifying an objective truth.

On the other hand, art is typically seen as an interpretation of a subjective sense of the outside world. This normative difference masks the power relationships within and between the two areas of knowledge-making. Here, STS offers a solution. Bloor and Barnes called for treating theories symmetrically to understand how science operates. In this way of thinking, both accepted and rejected theories require explanation of the social processes surrounding their respective status at any given time (Bloor 1976; Callon 1986; Barnes, Bloor, and Henry 1996).

This principle can also usefully be applied to the study of art. It should not be assumed that the reasons that the sciences harbor specific powers and the arts harbor others are the result of any normative facts about these knowledge systems. Instead, social explanations should be sought for these respective power structures in a given context. Interpreting art through the lens of STS offers an opportunity to reflect on the ways that this field thinks of itself. By treating science and art as equally constructed and employing some of the same social processes to ratify knowledge, STS can offer a fuller account of these processes. Considering the affiliations between art and science makes available a vast body of literature in art history, the sociology of art, aesthetic philosophies, and visual culture for understanding processes of category construction. Indeed, the art-science symmetry is so frequently internalized in art that engages with science that many such works explicitly comment on this idea. In *Latent Figure Protocol*, for example, Vanouse displays the tension between the viewer's expectations of a powerful "objective" set of gel electrophoresis bands and his doctored gels that produce specific images selected by the artist.

FRAMING ART IN SCIENCE AND TECHNOLOGY STUDIES

For decades, STS has sought to understand knowledge networks using the tools of the social sciences and humanities. Less discussed in STS are art networks. To be sure, the Society for Literature, Science, and the Arts and its journal *Configurations* have been recognized for some time as major forums for such studies. Some noted science studies researchers have explored issues of art, science, and knowledge production. In *Picturing Art, Producing Science* (1987), Caroline Jones and Peter Galison provided a catalog of central topics, with chapters by such scholars as Bruno Latour, Londa Schiebinger, Svetlanna Alpers, and Donna Haraway. In *British Naturalists in Qing China* (2004), Fa-ti Fan wrote about Chinese artists creating scientific botanical images for British naturalists. These images are especially notable for our purposes because the British naturalists had access to certain organisms only through the Chinese artistic rendering of them, as disciplined by British representatives in China. Among these scholars, Latour has perhaps gone the furthest in treating art and science symmetrically and taking up art methods by putting together the art exhibition and its catalog beginning with *Iconoclash* (2002) and *Making Things Public* (2005) and continuing to his most recent curatorial venture *Critical Zones* (2020). It is worth considering what may have caused some STS scholars to turn toward the arts. In the case of Latour, the modes of contact of art for reaching the public seem to have been central to the appeal as his focus has turned to the social knowledge and politics of climate change. Comparably, for the LifeSpace exhibition *Disentangle: Science in a Gendered World* (2019), a display of Londa Schiebinger's project *Gendered Innovations* (2019) demonstrated how accounting for sex and gender in the scientific process affects results. The work itself would have been recognizable to STS scholars but the format, a large infographic text located in the University of Dundee's Science Art Research Gallery in the School of Life Sciences was surely meant to reach a new population of viewers. The appeals of this work for STS scholars do not seem too different from those of scientists looking to make use of art for social ends sometimes zoned inappropriate in scholars or scientists' own boundary-making. As some avenues of activism are unavailable disciplinarily, one potential solution appears in the form of appeals and activism couched in the aesthetics and language of art.

At the same time, there are also philosophical reasons why STS scholars may want to focus on art as a comparative knowledge-making community. Studying art and science through the same methods is the practical and theoretical extension of the implication that art and science construct our world through the social relationships inherent in their own ways of organizing people and manipulating materials. In a multitude of everyday examples, we have become accustomed to easily distinguishing the products of these two systems. Sometimes, however, those processes align and the products of art and science become difficult to distinguish. Where boundaries blur, these objects have the potential to give rise to new understandings of the power dynamics between art and science.

Representations are the realm of both scientists and artists, but images in particular have been associated with artists. Yet image-making is crucial in scientific work. This is likely why STS studies of the arts have tended to focus on image-making, sometimes to the dismay of artists whose activities extend well past visual representation. The drive toward image studies has resulted in a rather cursory conception of art as essentially *visual* representation in science. In the same way that some art about science would be well served to better understand the more nuanced view of science that STS has provided, if STS broadens its sense of what art is and where it might be found in scientific practice, this would surely enrich its findings. This would have further implications for understanding the nature of science. As Boris Castel and Sergio Sismondo (2002) suggest, if observers attend to what scientists really do, rather than recycle celebrated but now-discredited stereotypes such as the lone genius or the objective machine, they will readily see sciences as arts.

Some art areas that overlap with science have also found quick harbor in STS, albeit separated from one another. For example, integrating sound studies into STS has gone a considerable distance in facilitating the study of other senses converted into representations that are used by both scientists and artists (Pinch 2011; 2013. Categorizing the arts through their mediums and focusing only on those elements that scientists use, however, can give rise to an emphasis on comparative technique. That may cause us to miss important epistemes and investigations of content that could explain why artists and scientists select one medium over another, particularly in situations where work may span the categories.

Art studies in STS have tended to be limited to those practices that seemed to have the potential to explain science. What STS considers "relevant" art might be expanded if art practices themselves are examined. The philosopher Dehlia Hannah's work on performative experiments, for example, suggests that studying artworks that mimic scientific experiments have the potential to help us understand the nature of experimentation as a practice of science. Hannah (2013) writes: "The emerging genre of performative experiments opens up a site of critical self-reflexivity within the methods and material of scientific practice itself, a site in which it is possible both to explore the cultural significance of scientific knowledge and to critique the empirical methods that are used to produce the scientific image of the world. Performative experiments are exemplary, in this respect, of a new form of critical literacy that arises at once within the sciences and the arts." This new form of artwork further clouds the separation between art and science by probing overlapping practices. It also has important implications for STS. Art and science themselves are not stable over time. Components may change, and with them, the relationship between art and science. Considering art and science as rhetorical devices can help us understand the fluidity of these categories and how an object can be labeled as art in one context and science in another.

Indeed, art may not be so different from science. Pioneering science studies figures such as Thomas Kuhn and Bruno Latour suggested as much when they reconceptualized areas of knowledge as the interactions between people and the objects they create. In his classic sociological work *Art Worlds* (1982), Howard Becker studied art using methods STS scholars would recognize from Latour's *Science in Action* (1987). In the spirit of Latour's call to follow scientists (1987), we may follow artists, attracted by the prospect of witnessing actors move liminal objects in and out of art and science worlds, and the worlds themselves changing and reorienting.

Becker argued that art is the act of a community. It is not simply that art is the physical product of an interaction of suppliers, dealers, critics, and consumers. Becker posited that art communities are held together by a belief in art, a claim that echoes studies of scientific communities. Becker's emphasis on the social aspects of art so resembles the ways in which STS scholars have approached science that it raises questions about the similarities and differences between these communities that are created and maintained and whether we can trust their self-imposed systems of categories. Becker defined what counted as art through participation and enrollment of individuals in a network, a notion not dissimilar from the network Latour posits for science. This book is rooted in an STS worldview in part because of how it treats conversations around art and science. Rather than tracing an art history or offering a specific set of definitions by which each concept is understood, I propose a more dynamic and flexible set of terms by making use of actor's categories and considering their understandings in context. Although this book primarily relies on actors' own words and actions to make sense of their lifeworlds, even for larger concepts related to the definitional terms at play in their particular cases, it is still useful to discuss some communities of practice working in this area and the definitions they collectively use. In the next section, I offer an overview of my methods in this book, and outline some of the terms regularly used by actors and those performing analysis whose terms of debate I make use of in this book.

APPROACHES FOR ART, SCIENCE, AND TECHNOLOGY STUDIES

This book explores art and science as categories through liminal objects. The cases were selected to showcase a diversity of contexts in which the idea of what counts as art or science is understood differently by the involved actors seeking to position themselves and their work in relation to these categories. By approaching the question through bounded cases built around specific materials and objects, it is possible to understand how these objects are fitted into art and science networks and knowledge communities and how arguments about their status are brought to bear on their position as well as the consequences of that positioning. The cases examine how such objects have been selected to represent different aspects of the art-science construction across time and in different contexts. Observable changes to the categorization of objects point toward movements in the way that art and science are defined. The reader will be able to think of many cases in which an object that appeared to be science or art in one context dramatically changed through time, space, or another perspective. These changes may also be brought about as the way art and science are defined changes or through the work of actors who regularly move objects between these frameworks.

The cases in this book demonstrate different power relationships between art and science. An STS analysis of these art and science works is, for example, set apart from an art history analysis, by the critical/historical understanding of positivism by STS. These understandings give ASTS scholars a platform from which to critique science and to hold it up with art as a cultural product for analysis. This will facilitate a more fully realized theory of the works of artists who are engaged with historical and current science materials and practices.

The cases in this book are analyzed using tools from STS to understand objects that occupy both categories. Many more applications of these methods to artworks, especially those engaged with science and technology, can be made and would reveal an increasingly complex history of how the categories of science and art have been used to position objects, people, and ideas.

Accordingly, STS can see the art world not as outside its interests, but as embracing a new set of actors for analysis and as sharing some central concerns. The processes of classifying knowledge are fundamental to understandings of use and value. As Bowker and Star (1999) have argued, systems of categories attempt to fully characterize the world through a given system. The possibility of the existence of overlapping or additional categories, particularly instances where objects, people, or practices might be categorized in multiple ways, calls into question such complete knowledge claims. Art and science are two such categories. Applying the labels “art” and “science” affect the kind of attention that people, objects, and ideas elicit from readers, viewers, and thinkers.

Seeing art and science as being on a par has implications for understanding both enterprises and for STS. Science studies tools can be used to better understand art as a social practice (Becker 1982; Rogers 2011; Hannah 2013; Halpern 2014) and many tools from art can be used to understand science (Rogers 2011; Rarey 2013). Carried to its logical conclusion, the assertion that science and art are equally constructed and equally important would deliver a version of constructivism with the potential to reform STS's disciplinary distinctiveness. Reflexivity is required with regard to the categories that people use to make sense of things, as well as to the value and power-orientation assigned to those categories.

The burgeoning field ofASTS is entering a stage with the potential to unveil new avenues of STS inquiry and recognize hitherto invisible practices of STS already underway in the arts. Work in this area has already explored material engagements (Shell and Wellerstein 2015; Rogers 2012); including installation outcomes (Hannah 2013, Rogers 2011), practitioner use of art and science (Lynch 1988; de Ridder-Vignone 2012; de Ridder-Vignone and Lynch 2012; Shell 2012; Schick and Witzke 2014), and studies of the two knowledge networks, framed as either adversarial, as in the two culture" debates (Ortolano 2009), or collaborative, as in the case of projects that are intentionally interdisciplinary (Halpern 2012).

Scholars of STS and visual culture have laid considerable groundwork for STS studies of art engaged with science, as well as STS analysis of historical and contemporary art practices within science. Historians Pamela Smith (2004) and Lorraine Daston and Peter Galison (2007) have mapped an early modern history of practices and objectivity that offer complex accounts of the origins of ideas now easily ascribed to science or art. Literary theorist Tita Chico (2018) has explored the way in which the British Enlightenment was enabled by scientific cultures distinguishing themselves from literary ones. She contends that science depended on literary knowledge to present its experimental findings and that literary concepts like the metaphor were central to the epistemic innovations of the period, thereby suggesting enlightenment science's dependence on textual accounts. It might be added that these texts and orations were ultimately literary propositions formed in specialized but recognizable genres. Curator and scholar Silvia Casini (2011, 2015) has used STS perspectives on visualization to examine medical imaging and her book *Giving Bodies Back to Data* (2021) focuses on the developments of magnetic resonance imaging. On the visual culture side, art historian James Elkins

(1997; 2001), information arts scholar Stephen Wilson (2001), and artist Beatriz da Costa and STS scholar Kavita Philip (2008) have covered contemporary collaborations and conflicts in the art and science space. Artist and analyst Chris Salter set the stage for mixing case studies from different contexts to make analytical points about art, science, and technology. Salter's first book *Entangled* (2010) used historical case studies to explore the role of technology in performance. His subsequent book *Alien Agency* (2015) provided further inspiration for potential methods and modes in ASTS by offering an ethnographic and experiential account of art in the making. What distinguishes ASTS studies is its adoption of an analytical mode of treating art and science as equally deserving of explanation and interrogation, even in the face of considerable differences in social power across actors and institutions, and between the categories themselves. Work in ASTS explicitly interrogates the differences and similarities between art and science.

METHODS AND CASE STUDIES OVERVIEW

This book presents case studies designed to complicate art-science comparisons by considering how actors in different contexts employed categories of art and science in positioning their work. Although the circumstances of each case differ, it is important to note that cases of art-science interactions are by no means uncommon. I selected cases reflecting a range of situations in which similar power dynamics have emerged, using each as an exemplar for the relative power orientation of art and science and the politics of their knowledge claims. I developed these cases using a mixture of methods including archival research, participant-observer techniques, online interactions, in-person interviews, and ethnography, with each case requiring somewhat different combinations of approaches.

Chapter 1 explores the activities of a renowned father-son team of artisans who produced glass models for use in biological classification and the efforts to collect and represent these works as art long after their use as tools of science. The glassworkers Leopold Blaschka (1822–1895) and his son Rudolf (1857–1939) studied accounts of sea organisms in making models for use in scientific research institutions in the late nineteenth and early twentieth centuries. Today, Cornell University holds an extensive collection of more than 500 Blaschka models, divided between its biology and art collections. I blended extensive archival research of these collections (both the artifacts and their supporting documentation) with interviews of people currently or formerly involved in curating and restoring them, with a view to investigating the epistemological underpinnings of the respective interpretations of art and biology communities of these artifacts.

This case reveals the art-science relationship to be more complicated than just an instance of artists working in the service of scientists. My research illuminated the ways in which the aesthetic of the naturalist and leading evolutionary proponent Ernest Haeckel found its way into the Blaschka models and was accepted as the "correct" style for scientific modeling for many years. Haeckel's aesthetics in turn informed the construction of the discipline of natural history. The rediscovery of the models at Cornell University in the early 1960s (Burnett and Eisner 1964) provoked a dispute between art and biology groups over whether these works counted as art or science or both, a controversy whose proximate concern related to the care and presentation of the models but that had larger philosophical implications. These interactions revealed that processes of boundary-making and remaking began from the moment the models were created and persisted over time in different contexts.

This case study problematizes the stereotypical power dynamic that imagines the artist in the service of science. The Blaschkas displayed the complex self-fashioning and object-positioning activities typical of artists but their agency was also symptomatic of the effect that art and science as social constructions has on the practice of art and science. The use and general understanding of the categories of art and science have practical implications for shaping objects and actor identities. The Blaschkas' contributions to natural history placed them in a position of direct observation and discovery, while also predicating their economic advancement on currying the favor of their scientific patrons (Halpern and Rogers 2013). This chapter tells the story of the Blaschkas as a means of reconsidering the position of artists implicated in scientific enterprises and their roles as knowledge-makers. Previous studies of art in science contexts concentrated on processes of disciplining artists to produce objective images for science applications (Daston and Galison 2007). These studies complicate the suggestion that the artist could be understood as an extension of the scientist. Uncovering artisanal epistemology, Smith (2018) is vital to understanding social relations between these groups. Smith (2004) has shown the crucial role of seventeenth-century artists in claiming to create a “new experimental philosophy.” In its most extreme form, this framing conjures the Aristotelian “living tool” metaphor that figures scientists as theorists and artists as makers. STS scholars have long debunked the fallacy of the thinker-maker dichotomy through concepts such as technoscience, which articulates relationships between science and engineering.

In contrast, the Blaschkas made significant contributions to science and positioned themselves as uniquely capable of doing so. This case begins the book’s exploration of art-science relations precisely because at first glance it appears to conform to stereotypes about art. The Blaschkas may seem at first simply to be following directions from the natural historians who bought their models. A closer examination, however, suggests that the division of labor between artisan and scientist was not so clear cut. The Blaschkas operated independently from scientists and participated in the scientific community, and their skill in glass working distinguished their work from other model-makers.

The story of the Blaschkas continued in the contemporary period as their work was repositioned by curators. Collection curators made use of art-science divisions to explain why the models should be conserved for artistic or scientific reasons. Some called on the same resources that the Blaschkas used to promote acceptance of their work as art or science. Over time, this process imbued the glass models with values recognized by the respective groups who curators hoped would support their conservation. By exploring curatorial choices to display the models at Cornell University at both an art and a science venue, active construction of definitions of art or science over time is cast into relief. Concepts of what counted as art and science changed according to context. Aesthetics played a role in the acceptance of models as suitably scientific.

In Chapter 2, I explore these power relationships through the physics photographs of the documentarian Berenice Abbott (1898–1991). I developed this analysis using curatorial methods that overlap with the STS application of the idea of interpretive flexibility. As a curator of many of the objects addressed in this book, I have been in a position not only to observe practitioners positioning their work as art and science but also to participate in heightening or dimensioning these calculations myself. I recognize this process as STS by other means, that is, curation as a form of critical analysis of the social relations of art and science. In many ways, the work of the curator evinces aspects of social and cultural anthropology. In engaging and working with artists, curators of necessity must observe, decode, and comprehend norms, mores, and social structures, although by convention these analytical acts are not necessarily reflexive and systematic. On the other hand, the self-aware curator is well-placed to derive deep insights from artist and science communities. As an STS practitioner, I have tried to imagine my curatorial work as a kind of qualitative fieldwork, and my movements onto the terrain of art and science as the acts of a participant-observer. As a method, curation of art-science has the potential to open fresh avenues of analysis by placing the analyst at one remove from the material practices of institutional science.

Abbott worked in a role that, like the Blaschkas, might on the surface be interpreted as service to the scientific enterprise. Her photographs played a pedagogical role and were based on the work of scientists. Yet Abbott situated her science images in a broader parallel project of advancing photographic aesthetics with a view to enlightening the public about issues of her day (Rogers 2015). Like the Blaschkas, Abbott made use of what she called a “realist” style that was commensurate with the needs of scientists at the Massachusetts Institute of Technology (MIT). However, her aims were explicitly to communicate, and thereby, democratize science. The artist as passive conscript in the machinery of science communication is a common trope among those seeking to explain their presence at sites of scientific knowledge production. Abbott bent this causal linearity because she actively sought scientists with whom to work. By the time Abbott received a commission at MIT, she had already written a manifesto on the subject and her quest to bring the public into contact with science had been underway for years. Scientists used Abbott’s work for pedagogical purposes but the photographer simultaneously pursued her own public interest goals. Abbott’s images of science hence represent the materialization of a philosophy of photography as a means of communicating realist ideas.

In Chapter 3, I explore a rather more complicated case of normative art-science work in the tactical media movement. In the early 1990s, a group of artists with leftist interests began using the technologies of the internet to intervene in debates about science, technology, and capitalism. Their use and knowledge of computing allowed them to outpace governmental and corporate entities as they began their forays into the digital commons. Like the Blaschkas and Abbott, such actors possessed a variety of technical skills necessary to realize their work. The goals of the Blaschkas and Abbott often aligned with those of their scientist counterparts, an alignment that served to mask some of their agency. This is not so in the case of tactical media practitioners. They are not employed by scientists and their goals are explicitly political. They use their technical means to provide political critiques. These practitioners have an agnostic relationship with the categories of art and science.

Unlike the Blaschkas or Abbott, who identified as artists, tactical media practitioners are more likely to subvert those categories or to self-consciously use them to forward their projects and philosophies. Studying this community posed special challenges. Few paper archives exist for contemporary art works in the vein of the tactical media practitioners, so I resorted to internet archives that catalog older websites, notably *The Wayback Machine*. I supplemented analysis of open-source materials with interviews of practitioners, which were often complicated by the not-infrequent efforts of the artists to enroll me in their work by performing personas from their interventions.

Chapter 4 is an ethnographic study of a bioart lab that brings together artists and scientists in a physical space of shared resources. SymbioticA was responsible for leading projects like *Fish and Chips/MEART* (2001) which functioned as both artwork and scientific output (Bakkum et al., 2004, 2007). As the artists obtained increasing degrees of technical skill, scientists became less vital to their projects. SymbioticA came to be a central node in an artist-dominated network because it was able to introduce artists to skills, materials, and a battery of scientists who have experience working with artists. Scientists remained important as allies at SymbioticA but were no longer vital to the creation of artworks because of the access the artists had to wet lab materials and their knowledge of laboratory protocols which put them in the position to continue to add to their repertoires using published results and their own experimentation. In such projects, technical skills, like those possessed by tactical media practitioners, were required to make the artworks function. In the hands of bioartists these substantive skills and interactional expertise were tools turned toward science to critique specific lab practices, biomedical ethics, historical wrongs, and projected futures.

Tactical media practitioners and bioartists have a critical edge not present in other artwork. Tactical media practitioners are concerned with using technology to make changes to corporate technical systems, yet their work requires digital platforms and makes use of popular ideas about hacking culture norms to create these critiques. The power delineations between art and science here are not straightforward, because these practitioners do not draw strict lines between art and science and are willing to refer to their work with any label that serves the politics at which their projects aim (Rogers 2011). In these instances, the tension between using and critiquing is acute. The actors make use of contemporary laboratory techniques to create work critical of biotechnology. When bioartists do critique the social context that produces science, their critiques are more pointedly aimed at the *practice* of science. Unlike tactical media artists whose primary interest is to deliver a political message, bioart critiques often focus on the details of scientific practice and their consequences, which makes it particularly suited to the dimensions of critical engagement that an STS analysis can offer. Bioartists, like STS scholars, do not aim to directly contribute to science, at least in the conventional sense. Rather, their work exposes new and sometimes troubling aspects of scientific work and serves as a textual or material critique.

In Chapter 5, I explore my own role in situating works as art or science in the context of my curatorial and research program *Art's Work in the Age of Biotechnology*, held at North Carolina State University in 2019–2020. In this chapter, I more fully develop the concept of curation as a form of critical analysis. In planning *Art's Work in the Age of Biotechnology*, I helped create a novel curatorial method that attempted to account for more voices than a traditional curator's choice by holding a pre-exhibition to obtain feedback from audiences and experts and a symposium to discuss the best ways of approaching the exhibition. Chapter 5 analyzes the way in which material and rhetorical resources are used by curators to situate art works. It considers the physical and textual contexts that curators can use to interpret lab or non-lab materials and explores the tensions of using versus critiquing science and technology manifest in contemporary artworks. The chapter also considers the resources curators deploy in staging works as art and science, exploring them in the context of recent new work engaging biotechnology, many created expressly for the 2019–2020 exhibition, by well-known and emerging artists including Maria McKinney, Joel Ong, Emeka Ikebude, Charlotte Jarvis, Jennifer Willet, Paul Vanouse, Joe Davis, Dana dal Bo, and Ashley Seifert. Some of these resources are provided by the affordances of the projects themselves, while others draw on conventions used in exhibitions in the art world and in science museums and centers.

These cases reveal the variety and complexity of the actors' use of the categories of art and science. Although these are certainly not special cases, we cannot take away a general lesson about how art and science categories interact. A cumulative effect in this sense is absent. Instead, through these case studies, doubt is cast on the idea that art and science can be thought of as stable categories. This shows how the method of accounting for material and rhetorical practices can reveal the construction of the categories of art and science in any other case we choose. Based on my findings, even cases that might appear from the outside to have very simple art-science relationships, may on closer examination reveal the complex structure of these categories in relation to each other. The elasticity of art and science is tested by the diversity of objects and situations that destabilize these categories and the multiple purposes they serve. The ideological fabric of art and science is maintained by rhetoric and rhetorically inflected materials.

TERMS OF THE DEBATE

It is important to acknowledge the variety of ways in which actors in these cases use the terms art and science. The science I refer to in this book is by and large what was once known as natural science, to the exclusion of social science as understood in North America, and as opposed to a more European sense of the term science, which tends to encompass both social and natural sciences. At the same time, the way in which science is historically situated has a considerable bearing on the choices and self-fashioning of the actors in this book. What counts as science (as opposed to a late stage of natural history) or what is understood as the preeminent science of the time affects both the work they create and the social situation of that work. Simultaneously the same issues are occurring on the art side.

What art was to the Blaschkas is surely rather different from what it is to tactical media practitioners. This comparative dimension is of great interest because it reveals the contextual nature of the relationship between art and science which shifts as actors make different use of the categories in different contexts. Recent and historical examples yield patterns in actors making use of the categories even as the definitions of what counts as art or science change. What is admissible as art (or as science) is heavily contested. The cases make use of actor's categories rather than scholarly judgements about which art or artists are admissible. For example, during the course of the research for this book, bioart moved from an uncanonized set of practices to a collected, awarded, and well exhibited artform even as it continues to engage with what were formerly understood as practices associated nearly exclusively with science. Similarly, tactical media does have on-going groups that continue to produce projects but tactical media is now understood by many practitioners and curators as a recent historical art movement that continues to influence digital and media art practice today. By the same token, some scholars might place the Blaschkas' glasswork in the category of craft which they would seek to excise from art history and there was a time when the photograph was a medium outside of art. (Indeed Berenice Abbott was among the photographers who worked to change this perception.) The most recent biotechnology-engaged artworks that I consider in the final case have a strong design lineage, particularly from critical and speculative design (Malpass 2019; Fortlano 2019) but that also takes theoretical and practical cues from human-computer interaction (HCI) user studies.

Critical design founders Dunne and Raby have suggested that design might be used as a medium for discussion (2001, 2013). Topics include the growth of these new design practices and outcomes, particular on-going forms of community engagement, platforms for online interaction, and participatory design/co-design hailing (Bødker 1996; Vertesi et al., 2017; Forlano and Smith 2018; Forlano 2019). Particularly notable among these further theoretical extensions are Carl DiSalvo's adversarial design, which examines how design can provoke and engage the political by using "the means and forms of design to challenge beliefs, values, and what is taken to be fact" (2015), and Bruce and Stephanie Tharp's discursive design, which explores how design might be used to prompt "self-reflection, igniting the imagination, and affecting positive social change" (Tharp and Tharp 2019). These designs regimes directed at questioning political and systemic issues have brought forward the limitations of some former understandings of what design can be. These new designs and their ways of complicating and undermining techno-solutionism in favor of social reflection are crucial to the types of critiques available in tactical media and bioart. Andy Stirling (2010) argued in *Nature* that experts ought to be "keeping things complex" when working with policymakers and perhaps the same should be true when working with the publics, because dimensioning complexity can have the dual effects of reduced information and reduced choice.[2] Many of the practitioners mentioned in this book seem to agree with Stirling's sentiment and even attempted to expose complexity further as in the case of the artists working with biotechnology in Chapter 5. These works gain new traction by expanding on traditions in public art and do-it-yourself (DIY) community centered art making by extending into methods familiar in STS that are used in design, including user studies and anthropological observations.

Indeed, many STS theories intersect with aspects of these design theories. These concepts of designs making sense of our proposed particular view of the world or social conditions would be familiar to readers of Sheila Jasanoff and Sang-Hyun Kim's 2015 *Dreamscapes of Modernity* in which they describe the sociotechnical imaginary as "collectively held and performed visions of desirable futures . . . animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology." Advocates of critical design might argue that these collectively-held possibilities can be evoked or even created through proposing possible designs that might reorder society, which suggests that society might be different through their affordances or posit new social orders through designs.

I note that the changes in the way that art is defined to include or exclude certain practices indicate that just as the ever-expanding frontiers of science's colonizing of new ideas and areas of study mean that what was formerly not a scientific subject may become one and what was once zoned scientific may cease to be, art also undergoes border policing and permissiveness. What is today accepted as an emerging or a newly minted art practice, may come to be seen as a central branch or may be pruned back and relabeled as a purely design project. In terms of this text, I attempt to remain neutral on these future-oriented questions and instead focus on how the actors are situating themselves and their work in terms of science and art and are influenced by other terms like design, technology, and engineering swirl in the related reaches of these actors' self-fashioning.[3]

LINGUISTIC PARADOXES IN ANALYZING ART AND SCIENCE

Querying categories presents linguistic difficulties because it is necessary to invoke *art* and *science* even as the aim is to show how they are indistinguishable at times. This was a problem I faced in talking with interviewees and in writing these cases because my own language tended to reify the very categories that I was looking to complicate.[4] If the use of the terms in context reveals that the two categories are used by actors to designate otherwise similar materials, protocols, and people, then maintaining separate terms might seem to undermine the idea that these undertakings are similar. The blurring of the art-science line occurs in different places in different cases: around the roles of the actors themselves, around the production of the project, around the institutions where the project is produced and displayed, and around the way the outcomes are situated.

Take, for example, *9 Evenings: Theatre and Engineering* (1966), a New York City-based series of events combining art and technology. Another distinct project that emerged from Bell Labs was Experiments in Art and Technology (E.A.T.). Founded by Bell Labs employees Billy Klüver and Fred Waldhauer, E.A.T. was an independent non-profit organization founded in 1967 (and based in NYC) in the year following *9 Evenings* (McCray 2020). In these instances, the roles of artist and scientist remained defined while the outcomes of these works were considered hybrid.

In other cases, however, it is the practitioners themselves who are seen crossing this line into a new identity. The Blaschkas, for example, referred to themselves as "natural history artisans." The construction of the terms and of the sites for the use of the division of these terms has created all kinds of difficulties across the academy such that claims are often reified by selecting what is included under the umbrella of these terms to support their positions. Indeed, even as I analyze the overlap in these two arenas to show that they are greater than typically assumed, the language of separation persists. It is necessary to use the terms even as these cases undermine them as stable and their distinctions blur.

This will be particularly apparent in the cases of tactical media and bioart. Artworks that do not support or celebrate science and technology are seen as outside science, whereas those that "explain" or celebrate science are seen as a legitimate part of it. If an art-science practitioner does not agree with the terms of a scientific argument or the way in which a new technology is deployed, that individual's work will be deemed nonscientific, similar to science work that goes too far outside a current paradigm, even if it conforms to conventional standards of observation and measurement. This phenomenon has been extensively analyzed in classic STS studies of gravitational waves (Collins and Pinch 1993), vitamin C (Richards 1991), and paranormal activity and unidentified flying objects (Pinch 1979; Collins and Pinch 1982). The position of artists, however, who many see as too perpetually and intentionally outside science institutions to comment on them, is often rendered mute in the context of scientific discussions.

Another problem of language arises when deploying terms, such as the *divide* or the *border* between art and science. When taken literally, such metaphors mystify rather than clarify the relationship. There are many other metaphors that are more suitable, but it is crucial to avoid confusing the metaphor with the relationship itself. This is the paradox of continuing to talk about art and science as separate entities: it can reinforce a boundary constructed by actors for political reasons. It is their reasons for labeling and relabeling entities that are of interest here. What social work is accomplished by labeling, for example, Vanouse's performances as art or science, and what rhetorical and material resources can be called upon to strengthen that assertion?

When I suggest that these actors use the categories of art and science for political aims, a broad definition of politics as power relations should be kept in mind. I use the term "political" in two ways in this book. The first is in the colloquial sense of a conventional political orientation. The second lies in literary critic Terry Eagleton's definition of aesthetics (1990). For Eagleton, aesthetics is whatever is left out of the Enlightenment project of rendering power through controlling knowledge (1990, 76): "It is as though . . . philosophy suddenly wakes up to the fact that there is a dense, swarming territory beyond its own mental enclave, threatening to fall utterly outside its sway. That territory is nothing less than the whole of our sensate life . . . [The aesthetic] is politically quite indispensable: for how can everything that belongs to a society's sensational life-'experience,' be allowed to fall outside the circuit of its reason?"

In the case of the Blaschka models, conventional politics unfolded in efforts to sell the models or to recruit funds for their maintenance. In Eagleton's conception, politics were those aesthetic qualities unnecessary for the success of these objects as scientific models, but that were nonetheless present and part of the reason for their acceptance. In the case of tactical media, politics is explicitly about critiquing state and corporate power. Bioartworks tend to focus on problematizing the stability, ethics, and power of science. The aim here is a better understanding of the ways in which classification takes place in, around, and to the inclusion and exclusion of objects, people, and practices in relation to conceptions of art and science.

MATERIALITY AND RHETORIC

Two primary categories of emphasis across the chapters are the rhetorical and the material. Rhetoric, by which is meant linguistic (textual or oral) support for a project, often points to materiality in arguing the "realness" or actualization of a given position. Simultaneously, materiality, the physical instantiation of the project (glass and animal glue, film developed into photographs, digital presence, and the like) is understood through and given meaning by accompanying rhetorical stances. Although these are not meant to be comprehensive categories, they give us a convenient division between times when materiality is central and occasions when the way people talk and write about their work comes to the fore. We may imagine that neither rhetoric nor material would be as effective without the other, but it is the way in which these two elements are more than the sum of their parts that is of concern here.

There are material ways in which rhetorical constructions are supported when actors are making claims. Studies by sociologist Erving Goffman, for example, explored the presentation of the self through clothing choices or what STS scholars might call technologies of identity (1959). Although it is possible to argue that materiality is only a resource for rhetoric, materiality can also be seen as a separate category, one that is sometimes deployed rhetorically. Pinch and Bijker's concept of "interpretive flexibility" allows us to see that at particular moments, materials can be resources for arguments and that the same material can be used to argue for very different concepts until "closure" is reached (1984). In short, it is not only the object that is liminal but its context.

Objects help us think, and so they help us argue. One reason for employing materials is that they can make effective arguments. STS scholarship has shown that technologies may precede the scientific understanding of an idea or may be co-produced with it (Latour and Woolgar 1979). Similarly, artists use their works both to formalize ideas and to argue for particular worldviews. To provide some organization to the many ways in which the art-science delineation is created, in these chapters, arguments made through objects are studied separately from rhetorical strategies. Rhetoric may, of course, employ the ideas connected to materials, but the actors in question make difference by employing the material itself as proof, even as those materials are unknowable without rhetorical descriptions. Rhetoric may shape context and the meaning of a material, but I distinguish this from working directly with materials. This labeling scheme will make it possible to think about the resources that people employ in making their arguments for what counts as art and what counts as science.

As questions are settled and materials come to mean specific things, they may appear unchangeable or difficult to change. Materials are vital in the worlds of the actors, and we gain a great deal by keeping them in a separate category, because it allows us to think about how the material, as well as the rhetorical, shapes its category status as art or science. Materiality can serve as a way of talking, signaling, or displaying—in short creating—the difference in the communities of art and science.

Their respective institutions help to provide networks capable of imbuing objects with network-specific meanings. The material can produce rhetorical effects by the way it is fashioned and positioned. To make the value of the material in relation to the rhetorical clear, the context of the cases will help us attend to the mixture of rhetorical and material that constructs categories. Changes in rhetoric and materiality signal shifts in art and science.

Science and Technology Studies has examined changes in the way that people understand objects, notably the circulation of immutable mobiles, evidentiary translations that are thought not to be corrupted even as contexts change (Latour 1986). Through the concept of interpretive flexibility, science studies have found new ways to think about materiality. It is important not to fall into thinking that the materiality of objects is stable. For example, the glass models created by the Blaschkas are materially different today in their various display and storage contexts than they were originally. Not only have restoration projects changed them materially, but the types of organization and display have also changed from attempts to illustrate the variety of species to presentations meant to attract attention for conservation reasons, and these contextual changes require specific material practices. Similarly, bioart materiality issues are complicated by the short lives of the living materials in these artworks. Typically, after a few weeks, installations are only available online. It is somewhat ironic that this art, which concentrates on issues about living things, can only be studied later in the disembodied ether of the internet. This change in materiality alters how the projects can be understood because many bioartists maintain that contact with the living subject is crucial to their artworks, yet most people experience these artworks via digital documentation. Such transformations must be accounted for when assessing how materiality is leveraged in the categorization of art and science.

PRECURSORS TO ART AND SCIENCE AND TECHNOLOGY STUDIES

Art historians have written extensively about science, though they do not treat the subjects as being symmetrical and often appeal to positivist conceptions of science and objectivity. Some, like Martin Kemp, an art historian and Leonardo da Vinci expert, see art and science as different lenses to view the world. Kemp argues that there are structures behind the natural world that manifest themselves in different ways in art and science (2006). He calls these “structural intuitions,” and they include basic life processes and geometric patterning. Kemp’s ideas seem to be in line with how he describes his interest in da Vinci, as a seeker of the “universal.” This may seem naïve to many STS scholars, but Kemp’s motives are appealing. He seems to want to make sense of the potential comparisons between art and science and approaches this goal through an interest in the content of science and art images. Rather than approaching the similarities as something created by the cultures of the two groups, Kemp sees the similarities as being produced by interactions within the same world (2000). Although this symmetry is admirable, Kemp assumes that their similarities are derived not from interactions within social structures, but from the natural world, which he believes informs both science and art. As Latour (1986) suggested, however, our best option for moving forward in the study of the visual is to look at the goals of visual production.

Kemp is aware that objects do change labels. He emphasized the use that Renaissance artists made of ideas about optics and seeing, ideas now associated with science (1990). Art historian Samuel Edgerton also worked on the Renaissance investigation of linear perspective, exploring how the illusion of depth on a flat surface informed both art and science (1975) and later, the complex relationship between technologies of seeing and Christian ideology in that period (2009). This impression of the two worlds’ similarities was an important departure from work like art historian E. H. Gombrich’s *Art and Illusion* (1960), which proceeded from the assumption that different cultures depict and see the world differently. In Gombrich’s analysis (1960), art started from a culturally embedded idea, rather than from an observed object. The idea that visual depictions are based not only on optical stimuli but also on ideas about the world has a parallel in the STS concept of theory-dependent observation. In other words, scientists’ trained ways of seeing alter what they are able to observe (Kuhn 1962; Lynch 1988).

Edgerton continued his work in this area with Michael Lynch in a 1988 study of the importance of aesthetics in contemporary astronomy.

It revealed the ways in which scientists talked about image manipulation, particularly their avoidance of language that involved aesthetic choices as an important factor in how they understood what they were doing. Though their actions were in essence the same as those of visual artists—modifying the images—their rationales for doing so were different. The astronomers that Lynch and Edgerton studied claimed aesthetic choices only in cases where they were creating "pretty pictures" and described similar processes performed on data as making the phenomena that they were interested in more visible (1988). This study was groundbreaking in that it turned away from asking how art is parasitic upon science and instead inquired about the use to which scientists put their conceptions of art.

Art historian Svetlana Alpers raised questions about the legitimation of images through pictorial or textual means and helped launch the trend of understanding visual experience as being central to social identity, and therefore, social interactions (Alpers 1983; Abell 2007). In *The Art of Describing*, Alpers wrote: "Already established pictorial and craft traditions, broadly reinforced by the new experimental science and technology, confirmed pictures as the way to new and certain knowledge of the world" (1983, xxv). This raised the potential of seeing images created for natural history and then science purposes as potential mirrors to social identity. Sociological ideas about identity are important for this study because each practitioner worked to shape objects and practices, in part, as a reflection of self. Being accepted as a model-maker for scientific buyers or a photographer at MIT meant bolstering some notions about who artists are while complicating others. Bioartists often refer to the process of identity-making as "wearing lab coats." Tactical media practitioners, on the other hand, present different identities in different contexts, and are deployed as tactical media tools. The ideas of Steven Hilgartner (2000), Judith Butler (1990), and Erving Goffman (1959) on performative identity construction as an explanation for the similarities between the usual presentation of self and the presentation of a fictional self helps to explain both the positioning of actors in these case studies as artists or scientists and, in the tactical media chapter, the more complex characters the actors create through their projects.

Despite a few important exceptions, in STS it has been generally thought that although artists might draw on scientific tools, play on scientific themes, or be employed to praise scientific discoveries, the relationship was dependent: artists followed scientists. Art, therefore, was instrumentalized in the service of science. Many large bodies of contemporary artworks are re-contextualized scientific images, ranging from the work of Felice Frankel at MIT to nanoart galleries which were crucial to the promotion of the emerging science of nanotechnology (de Ridder-Vignone 2012; Frankel and Whitesides 2009; Frankel and Whitesides 2008; ImagineNano 2011; Hayles 2004). Ironically, these moments of images moving from microbiology, astronomy, nanoscience, and many other scientific fields into art may serve to reinforce the art-science boundary. Science images directly deployed in artistic settings, which could be called science ready-mades because the materials remain unchanged while their meanings change, tend to privilege scientific imagery in its own terms. The "naturalness" of the image, that is, the fact that it was not considered to be altered for use as an art image (despite whatever inventions were necessary to render it for the science context) and the ability of scientists to produce works accepted as art-museum-ready, are the results of the privileged position of scientists as image-makers.

Other scholars have been more interested in the crossover of theories from science to art and the anticipation of new ideas from science to be used in art. Barbara Marie Stafford (1993; 1994; 2007) has argued that image-makers should seize upon the discoveries of neurobiologists to better understand cultural objects. More recently, she has written on potential exchanges between the humanities and neurobiology (Stafford 2011). Although many of her recommendations follow older assumptions about art making use of scientific discoveries, Stafford does see room for science to benefit from new ideas in art (1993). Theorist Katherine Hayles was interested in the impact that digital technologies and arts and the humanities have on one another (1999). Hayles also wrote on the convergence of the humanities and other new sciences including chaos theory and nanotechnology (1991). Hayles was attentive to the role of humanists and artists, particularly in the case of such scholars who worked on nanotechnology. She was especially interested in how those roles served to heighten the appearance of the importance of the new science even as the content of the artists' work might be critical of the emerging science's ideas. Others like Edward Tufte (1983) took seriously the possibilities for improving the understanding of technical images through standardizing particular characteristics. For Tufte, art was a method to improve science images. Scientists and science communication scholars have called on the arts to improve science communication, whereas artists and art historians have called for science to be incorporated as a subject and a medium. Relatively few scholars, however, have treated the two communities as capable of benefiting one another on equal terms.

ART AND SCIENCE AND TECHNOLOGY STUDIES

The approach in this book is to apply STS tools to examples of artistic practice that are engaged with science, thus offering new ways of thinking about people and objects that have often fallen outside the scope of STS research. Although there has been substantive STS scholarship on visualization and the use of images in scientific inquiry (Fan 2004; Jones and Galison 1998; Hacking 1983; Daston 2004; Dumit 2004; Burri 2012; Casini 2011), the realm of art history, sociology, and criticism has mainly been considered of interest insofar as it may help to analyze scientific images. In the past decade, however, many new studies by STS scholars of art have appeared (Rogers et al. 2021; Salter et al 2017; Calvert and Schyfter 2017 Casini 2015; Halpern 2015; Halpern 2014; Hannah 2013; Rogers 2011). These studies differed from previous art and science work because of their view of science and technology as a constructed and cultural practice that is not posed as being at odds with art.

The groundwork for new ASTS studies was laid through foundational texts by art historians and STS scholars who treated art symmetrically with science. Art historian Caroline Jones and STS scholar Peter Galison's *Picturing Science, Producing Art* (1998) was important in shaping possibilities for the nascent field of ASTS. This edited volume included key scholars in this area (Latour, Haraway, and Alpers) who analyzed the fields of inquiry that exist between the history of science and the history of art. The book demonstrated the rich variety of examples that involve both scientific and aesthetic questions, as well as insisting on similarities between the two communities in terms of "knowledge-making," "image-making," and "object-making." Building on the conception of art as a knowledge-making community and on the value of this type of inquiry for asking new questions, this book draws on new aspects of older STS subjects. In moments when the boundary between art and science becomes more permeable, it is easier to see that the established definitions are simply being reproduced when science and art achievements are catalogued (Jones and Galison, 1998).

In *The Body of the Artisan*, Pamela Smith offered a historical account of the convergence of two previously separated modes: the making of things and the making of knowledge (2004). Smith showed that beginning in the fifteenth century, artisans began situating their art and texts to make the connection between "making things" and "knowing/representing nature." Smith's investigation made possible the idea that these seemingly closed definitions can be reconfigured. Marga Bijvoet (1997) and Sian Ede (2005) opened provocatively by asking if science is the new art by pulling on stereotypes and expectations around what art and science do. Ede writes in *Art & Science*: "Scientists weave incredible stories, invent wild hypotheses and ask difficult questions about the meaning of life. They have insights into the workings of our bodies and minds which challenge the myths we make about our identities and selves. They create visual images, models and scenarios that are gruesome, baffling or beguiling. They say and do things that are ethically and politically shocking. Contemporary scientists frequently talk about 'beauty' and 'elegance;' artists hardly ever do" (Ede 2005).

In short, Ede suggests that art concepts can be as useful in science as in art. This point is also made by art historian James Elkins (1999) in his attempt at consilience with Galison's *Image and Logic* (1997), which examined the role of the image in modern physics. Elkins has made several attempts to bring art history into conversation with STS works on images, or what he calls *representations,* for the sake of creating a shared language for art history and STS (1995). Elkins hoped that this shared language would allow art historians to expand their vision of relevant images and STS scholars to take a more nuanced view of images in their work. As a pioneer in the study of visual culture, Elkins has been interested in focusing the tools of art history on non-art, including scientific and technological images. His engagement with science studies recognized the potential overlaps that already exist between these fields.

It is worth noting that although STS is only beginning to take account of artworks directed towards science, some groups of artists are already intensely aware of STS ideas and draw on them in their works. The perpetual involvement of artists both as workers in the scientific enterprise and as social critics engaged with society's ideas about science and technology reveals that artists have long been close to science. As we shall see, the tactical media practitioners and bioartists engage with many of the same concerns expressed in STS studies literature. Calvert and Schyfter (2017) explored some of the ways in which science studies scholars might learn from artists and designers, particularly in relation to emerging technologies such as synthetic biology. They argue that artistic engagements with science look much like STS engagements, with the crucial difference being that artists create material responses whereas STS scholars create texts. Roosth's contemporary account of the lifeworlds of synthetic biologists (2017) shows the relationships between biological making and knowing. Like other engineering and technoscience pursuits that preceded theories of how technologies worked, synthetic biologists have co-produced theories of life alongside their ability to intervene in its definitional processes. Readers encounter an extension of the process of engineers and data scientists entering the world of biologists which is comparable to the process of developing genetic modification technologies at the turn of the millennium. She explores the role that biohackers and artists have had in shaping synthetic biology and its perception in and beyond the sciences, while observing the limitations of the possibilities for intervention available to these non-institutionalized researchers.

Artists themselves have written extensively about their own work. The edited volume *META-Life* (Bureaud, Malina, and Whiteley 2014) includes extensive artistic reflections on works that the authors and curators created in the area of synthetic biology and artificial life. These publications by artists and art world professionals are attempts to grapple with specific issues in their own works and the works of related artists. This suggests that the artists believe that their work is under-theorized. As one SymbioticA student explained to me in an interview, bioartists are forced to spend a lot of time explaining their work or including theory directly in it. This may be a posturing move in which the artists are announcing themselves as misunderstood, but it could also be that art criticism lacks the tools to deal with the technical and science-critical aspects of many of these artworks. Art critics are by and large not familiar with science and technology in the ways that these artists are, so STS scholars are well placed to add to the critical body of work around this art.

A case in point is *Tactical Biopolitics: Art, Activism, and Technoscience* (2008), a volume edited by da Costa and Phillips. Bringing together scholars and artists who are writing about the theoretical aspects of their work, da Costa and Phillips explore how contemporary art engages biopolitics. The text has the advantage of mixing the voices of scholars and artist-activists, which demonstrates the variety and sophistication of artists' critiques of science and technology. Other scholars have examined art-science intersections by organizing work around a particular science or in the form of a sampler, documenting many artworks organized by the science with which the artists engage. One such example is Stephen Wilson's *Art + Science Now* (2010). These book groups artworks by the science that they use or critique and covers a variety of science-engaged artworks from robotics to nanoart. Another approach is to focus on a single science subject as in artist Suzanne Anker and STS scholar Dorothy Nelkin's *The Molecular Gaze: Art in the Genetic Age* (2004), which deals with art that stems from the questions and images around what the authors call "the genetic age." This focus allows readers to consider the role of specific scientific developments, in this case genetics, to contemporary art. The book discusses some artistic responses to the coming of age and futures of genetics. As SymbioticA artists Ionat Zurr and Oron Catts noted, it also included some artists, like themselves, who do not work with genetics or consider their artworks to be a response to the genetic age (Zurr and Catts, 2005). Another scholar who has appraised and analyzed artworks relating to a specific scientific area is Lea Schick, who has examined art and energy projects (2016). Schick pointed to the way in which the vitality of infrastructures fundamental to the use of energy tends to pull artworks toward modes that make visible these infrastructures. Put another way, these infrastructures might be thought of as implicating the artists in their terms even as the artists launch interventions into these seemingly stable systems and offer imagined designs and demonstrations of new configurations for energy politics.

No study of art and science can proceed without mention of Daston and Galison's *Objectivity*, an account of the construction of different types of objectivity: trained judgment, mechanical objectivity, and truth-to-nature (2007). In this book, the authors historicize the concept of objectivity and briefly examine its counterpart, subjectivity. This shows the categories to be in flux from the outset and complicates the binary mapping of art and science onto subjectivity and objectivity, making way for a more nuanced view of these categories. Their historicization of objectivity implicitly offers the same critique of subjectivity. By undermining the idea that objectivity and subjectivity are stable categories, Daston and Galison effectively complicate one standard line of argument for the separation of art and science knowledge on the basis of associating subjectivity with art and objectivity with science.

There are a small group of nonetheless important examples of art-science related work produced for art world contexts by STS scholars. The images produced from the 2007 Museum of Modern Art show *Design and the Elastic Mind* were appropriated as illustrations by the STS journal *Issues in Science and Technology* (Antonelli 2008). Bruno Latour, along with Peter Weibel, curated an art show and created the related publication, *Iconoclash* (2002). The show was held at the Center for New Art and Media (ZKM) in Karlsruhe, Germany, and dealt with the destruction of a range of icons from science, religion, and art. These collaborations demonstrated the STS interest in and potential overlap with the study of art but were based on the assumption that art could advance understandings of science and technology. In this sense, STS scholars themselves instrumentalize art. ASTS offers a chance to see art and science on an equal footing and to consider what STS might add to our understanding of art-science work.

In art, STS stands to gain another area of study: thinking about how knowledge is arranged, divided, and brought together into the categories of art and science. Artworks that take science as a subject or source of technical knowledge may be enriched by a more sophisticated contextualization. STS can be a lens for viewing certain kinds of work that have been considered to be “art” works, thereby expanding the realms in which STS tools may be employed. It also asks us to expand the typical definition of knowledge production to include art. These cases demonstrate what it means to use STS to study practices that straddle art and science and to analyze how these categories are made more or less flexible through actors’ specific uses of them. Bioartists, for example, have varying views about the use of the term *bioart*. Some regularly employ the term because they believe that it accurately describes their fusion of art and biology. Others object, believing that their attempts to position themselves as artists who are critiquing biology is lost in the portmanteau quality of that term.

SEEKING SYMMETRY

Treating art and science symmetrically in the STS sense means being agnostic about their claims to particular knowledges (Barnes, Bloor, and Henry 1996). Causality, impartiality, symmetry, and reflexivity in the study of scientific knowledge can be applied to studies of art and science and yield new insights that avoid bias toward "successful" work in either area. It will also help avoid explanations that are dependent on eliminating the social factors crucial to the production, assessment, and dissemination of these works. Similarly, ASTS can learn much about both by examining artistic and scientific forms of knowledge symmetrically and impartially. STS sees science as a network of people and objects with complex practices and varied goals and should see art in the same way. If these two categories are seen as separate pathways of thought or exclusionary angles on the subjects, it can be very hard indeed to imagine that they could overlap. By understanding art and science as groups of people and things, it is easier to see how each may borrow from the other, so that individuals may participate in both at once without violating philosophies or principles.

The cases in this book focus on practices and networks to comment on their relationship rather than to assess their value, as opposed to valuing knowledge produced by either community against the other. This approach requires a focus on materials and the ways in which people weave together ideas to represent actors' realities and to signal their membership in the networks of art or science. I examine how these collections of people, objects, and rhetoric create the categories themselves, paying particular attention to the way actors talk about these categories and the implicit definitions they use.

Symmetry does not necessarily mean oppositeness. The difference between art and science is often naturalized as a set of opposite axioms (relies on history, divorces itself from history; objective, subjective) purported in some accounts to be stable. As these cases will show, considering applications of art and science in context requires closely considering how these definitions are used. It is possible to denaturalize them and create suspicion around what has been identified as a natural division. Through case study analysis, the categories of art and science can be shown to be produced by the discourse and material work of those who want to position themselves in the respective networks. Artists and scientists, however, may not think that they are working to posit themselves particularly in relation to the "other" network. In this way, they may have more in common than they realize because such actors are continually aware of boundaries of science/nonscience and art/nonart.

The history of an object's former positioning does not necessarily fall away even as new meanings are added to its labeling. Art or science labeling often remains to be played with in new configurations of rhetorical and material practice. Some contemporary artists do this consciously, but I would argue that for most thinkers there is a constant, if unconscious, mixing of the material and the rhetorical in support of their claims and arguments. Many of these projects leave the question of the distinction between art and science unresolved by simply raising the existence of the mixing of science and art without considering the reasons for the muddled distinction.

Signs, stories, and things are created to signal something beyond themselves. In this case the respective categories of art and science do not exist without the stories and things that make them up. Language is an elegy to the absence of objects and ideas. The thinking of Jacques Derrida is instructive here: "Through this sequence of supplements a necessity is announced: that of an infinite linked chain, ineluctably multiplying the supplementary mediations that produce the sense of the very thing they defer: the mirage of the thing itself . . ." (1976, 157).

This categorization is not, however, simply a matter of language or of ways of talking about professional identities that enable understanding. Materials are also employed, and these objects provide the means for observing the naturalization of the categories. We may close our eyes and think that categories are made by language, but on opening them we will have to work to see material objects in a new way, because they have been crafted to confirm our current conceptions of art and science. It is not that those objects are real and that we must accept them as the order of things but that they have been crafted to convince us that the world operates in particular ways. Our objections to the concept that language determines what we can think finds good evidence in the importance of materiality and the value of thinking with objects. Ideas and objects can fold completely into one another.

Using STS methods derived from the social construction of technology and actor-network theory emphasizes that the individual actors and their networks create social meaning for liminal objects, as well as for the social movements that coalesce around them and reframe their meanings. It is instructive to recall the example that began this introduction. In *Latent Figure Protocol,* Paul Vanouse reframed the idea of DNA fingerprinting using a series of gel electrophoresis trays filled according to a software-based ordering. The title of the project is a play on the idea of latent fingerprints which, although invisible, can, through crime lab techniques, be made visible, identifying the perpetrator. STS scholars (Lynch and Cole 2005; Lynch et al 2008) have been interested in the cultural and political meanings of refereeing to the sets of bands formed in these trays as fingerprints and the legal consequences of this metaphor.

Vanouse is also investigating another metaphor, that of DNA fingerprinting. For this project, Vanouse uses the same scientific equipment used to prove guilt in suspects to make a very different point. He might well argue his point only in text but because those who oppose his viewpoint are working with materials, his argument is made more effective by offering material resistance. His demonstration shows that by working out the lengths of strands cut by known enzymes, he can create any image in the gel tray. This pictorial use of the gels has the potential to undermine our confidence in the stable images, and therefore in the objectivity, of DNA fingerprinting. The copyright symbol he often chooses to make particularly suggests a suspicion around the commercial use of this technique. His use of the same technology for a new purpose successfully deconstructs the absoluteness or expected objectivity that we have for a technology that claims to sort the guilty from the innocent.

Vanouse's work would make little sense, however, without the social groups who use, support, reject, and critique the technology's application in criminal investigations. The demonstration relies on the audience's familiarity with at least some of the stakes of the technology for the relevant social groups. The piece operates as part installation and part performance. Vanouse displays both the already-run gels, and videos of the gels, and, on specific occasions such as art openings, gives a short lecture about the piece, explaining both the science and some of the implications of it for DNA fingerprinting. Hannah has argued that the study of "performative experiments" has the potential to offer insights into experimental practice in the sciences (2013). Translating ideas into material practices, in the form of experiments and vice versa, is a fundamental idea in both science and art; indeed, both groups see this act as central to their work.

The science and art in every historical moment are intertwined, each affecting the other. It is impossible to imagine SymbioticA's activities outside the context of contemporary ethics and biotechnology. It is equally impossible to imagine nineteenth century natural history without the contributions of representational artists like the Blaschkas to the scientific studies of that day. This book shows that the interactions of particular moments in the history of science relate to contemporaneous moments in the history of art. Art and science cannot be reduced to rhetoric or materials. Neither objective properties nor the consequences of framing seem likely to offer a complete picture of either realm. Reconnecting these ideas with the practices of people clarifies the relationship between the ideas of art and science, the practices involved in each category, and the people who create these distinctions.

2

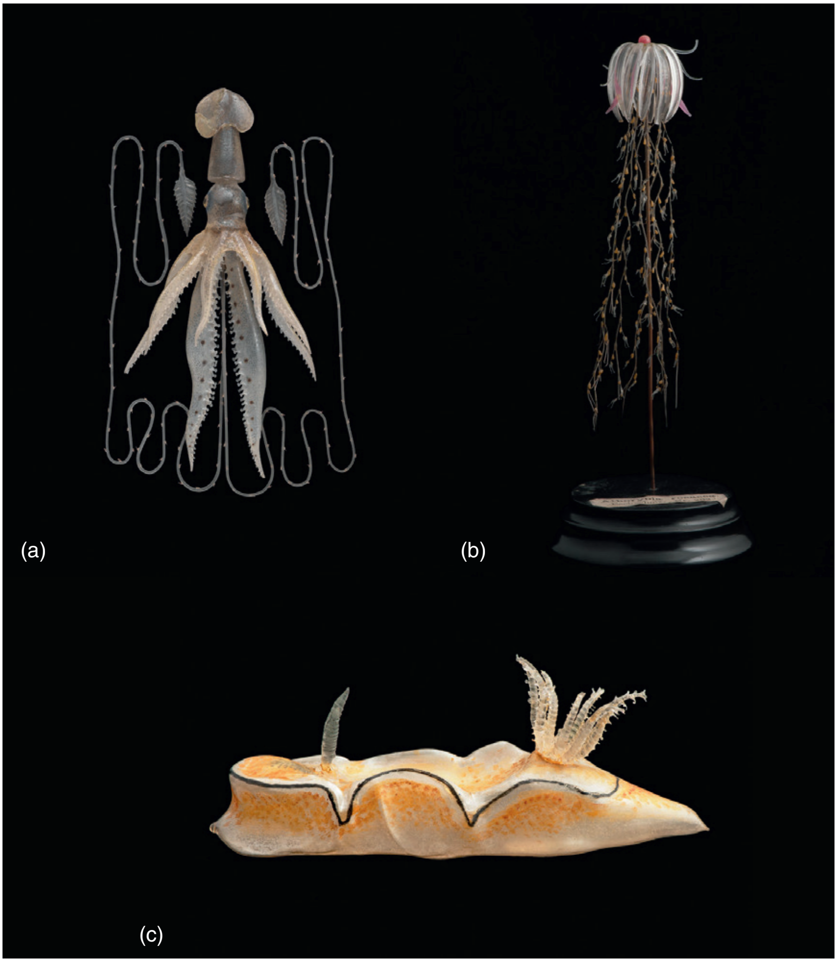
POSITIONING AESTHETIC KNOWLEDGE: THE BLASCHKA MODELS

“My father used to say,
Superior people never make long visits,
have to be shown Longfellow’s grave
or the glass flowers at Harvard . . .”
Marianne Moore, from the poem *Silence* (1924)

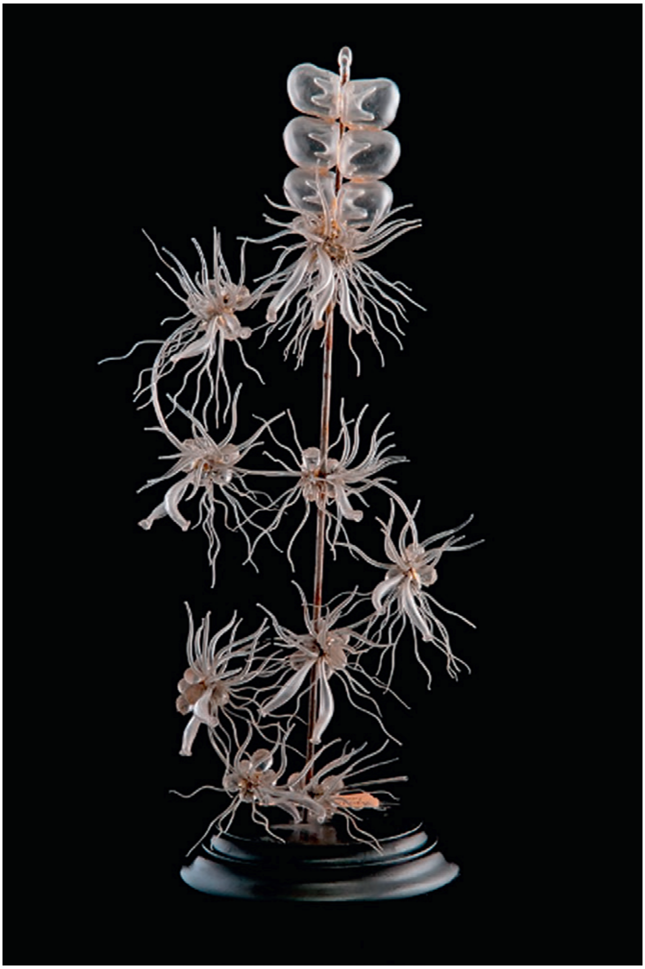
Visitors who have encountered the Glass Flowers at the Harvard Museum of Natural History might, if they were to glance into the display case at Cornell University’s Herbert F. Johnson Museum of Art, recognize the lifelike sea creatures displayed within as products of the same creators. Nudibranchs, jellyfish, coral polyps, and anemones, magnified and life-size, are wrought in exquisite detail, all in translucent color. The first time that I saw them, I was headed between floors of the museum, which is organized as a study collection so that one can take it in very much like a time-culture machine. Since that time, the model’s intellectual patron and the father of chemical ecology, Professor Tom Eisner, recounted to me on two occasions before his death the moment when he rediscovered the models in a forgotten dilapidated hallway case. That instant of recognition, when the sense that these models were real animals, faded into the clarity that they were surely those made by Leopold and Rudolph Blaschka, blends with Eisner’s vivid recollection of the models in a far less prestigious and pristine state. In a word, these models, at Harvard or Cornell or indeed in their many other university and museum collection spaces around the world—in perfect condition or awaiting restoration—are arresting.

The models are not designed to look, as some of the Blaschkas' later botanical specimens do, as if they have been plucked as specimens from their ecosystems. They aim at verisimilitude, but they also reflect the eye of their audiences and what their creators imagined lived under the sea. By creating these glass models, Leopold (1822–1895) and Rudolph Blaschka (1857–1939) were solving a problem for scientists: how to provide stable representations of difficult-to-conserve specimens. The marine models represented the color and form of these delicate organisms typically lost in attempts to collect, transport, and preserve them. They appear lifelike, as if they are still underwater in their native habitats. These marine marvels preceded the father–son team's exclusive contract with Harvard University, which would yield more than 4000 botanical models (Harvard 2018). The earlier models are part of Cornell University's collection, begun by University President Andrew White in 1882 at the urging of Professor John Henry Comstock and purchased through Henry Ward's Natural History Establishment. Cornell's treasury would grow to 570 models, and, though many still await restoration, a selection of these models is on display in both an art and a science venue on the Cornell University campus (figures 2.1 and 2.2).

Leopold and Rudolf Blaschka created important scientific collections for research institutions worldwide. Working in an artisanal tradition of creating scientific representations for study and pedagogical purposes and guided by published scientific descriptions of organisms and atlas drawings, the pair made models from glass, animal glue, and paint that were acquired by institutions in Europe, the United States, Japan, Australia, and India (Miller 2008; Dyer 2008).[1] These artifacts are an example of a class of object that in some contexts is regarded as art and, in others, as contributions to science. Importantly and perhaps counterintuitively, their value in the one arena contributes to acceptance in the other. In this manner, the glass artisans contributed materially to the scientific discourse, education, and research of their time. The preservation of these models in the contemporary context is predicated in part on



2.1 *(a) Chiroteuthis veranii* (long-armed squid). Glass model produced as *Loligopsis veranii*. *Source:* Cornell Collection of Blaschka Invertebrate Models. Photographer: Corning Museum of Glass. © Image: Cornell University/Courtesy of the Cornell Collection of Blaschka Invertebrate Models. Used by permission. https://digital.library.cornell.edu/catalog/ss:20108240 (b) *Athorybia rosacea* (Siphonophore). *Source:* Cornell Collection of Blaschka Invertebrate Models. Photographer: Claire Smith. © Image: Cornell University/Courtesy of the Cornell Collection of Blaschka Invertebrate Models. Used by permission. https://digital.library.cornell.edu/catalog/ss:20107977 (c) *Doriprismatica atromarginata* (black-margined doriprismatica). Glass model produced as *Casella philippinensis*. *Source:* Cornell Collection of Blaschka Invertebrate Models. Photographer: Claire Smith. © Image: Cornell University/Courtesy of the Cornell Collection of Blaschka Invertebrate Models. Used by permission. https://digital.library.cornell.edu/catalog/ss:20108093 https://digital.library.cornell.edu/collections/blaschka.



2.2 *Apolemia uvaria* (string jellyfish). *Source:* Cornell Collection of Blaschka Invertebrate Models. Photographer: Kent Loeffler. © Image: Cornell University/Courtesy of the Cornell Collection of Blaschka Invertebrate Models. Used by permission. https://digital.library.cornell.edu/catalog/ss:20107973.

the continuing interest of curators and the public in the aesthetic qualities of the models. This process of valuing qualities thought to associate the objects with either art or science sheds insight on the resources marshalled by scientists and artists in the contemporary period to contextualize, value, and preserve this work.

This case offers new ways of interpreting artists' roles and contributions to science. Past studies have seen artists as the bodies or hands of scientists even as they worked to clarify the position of artists as makers of knowledge vital to scientific enterprises. This chapter might be expected to demonstrate the interaction of artists as workers for scientists but instead shows that the conception of the artist–scientist power dynamic underplays the contributive role of artists in the scientific enterprise. A more extensive study of artists who had previously been understood to be instrumentalized for the work of science may well reveal that many such artists are conducting their own forms of knowledge production that are vital to scientific understandings. The instrumentalization of artists can lead observers to black-box important practices, which must be accounted for in complete studies of science. In taking stock of the roles of artists in science, the supposed boundaries of their crossdisciplinary work become more complex and less readily separated. The products of these artists' work, the models themselves, take on a liminal quality as contemporary actors actively curate them into both art and science collections.

The Blaschkas produced representations that scientists themselves did not have the technical skills to produce. The products were fundamental to the practice of science, yet the skills themselves are often defined as lying outside the project of scientific knowledge production. This producer-consumer relationship is thought to put the artists in a position of economic dependency. Even in this configuration, however, the relationship between art and science is blurred by the contributions of the practitioners in question.

The Blaschkas' careers in glass working progressed from creating eyes for taxidermy, to fashioning marine invertebrates and magnified models of microscopic organisms such as radiolarians, and finally to the botanical specimens at Harvard (Schultes, Davis, and Burger 1992). Finished by Rudolph after his father's death, the Glass Flowers are widely considered the zenith of their oeuvre and are a tourist destination in and of themselves. In 1951, the poet Marianna Moore implied that elites knew all about these treasures. The masses, however, do have to be shown the Glass Flowers. Each year, some 180,000 people visit Harvard's Natural History collections, and the Glass Flowers are one of the most popular exhibits and many more experience the models online through the Harvard College website. Harvard's motto for them is a "marvel of art in science and a marvel of science in art," an apt description for the objects that have since their origins occupied a liminal space. Naturalists in the Blaschkas' era and since have praised them for their lifelike qualities, and they continue to be revered for their realism (Daston 2004). The conviction that these models are different from comparable objects because of their realistic style is a claim made by both art and science curators eager to frame the Blaschka models as being singular. The Blaschkas' technical ability to render realistic figures is claimed to be beyond the capabilities either of their peers or of current glass artisans. Regardless of their veracity, claims of singularity have proven useful in helping curators demonstrate the importance of preserving the Blaschka models.

In the classic understanding of artists creating representations for scientists, it is assumed that whoever made these objects must have worked under the direct tutelage of natural historians possessing a sophisticated knowledge of anatomy. Rendering the accurate number of tentacles on jellyfish or of cilia on a microscopic organism represented as a scaled-up model was no trivial matter in this line of work. The Blaschkas were artisans, but they were also savvy independent businessmen who saw an opportunity to enter into the scientific community. They sought to develop the requisite observational and technical skills by keeping an aquarium, studying contemporary natural history publications, and corresponding with leading naturalists. To create the botanical models for Harvard University, Rudolf would eventually travel into the field to find the organisms that they would represent.

Although it may now seem to us that glass is the obvious or perhaps only material for creating such models, this story is not so much one of selection as identity. Afterall, images rather than dimensional models or sculptures were used extensively since with images, which had already been brought to great heights by the 15th century (Tomasi and Hirschaue 2010). Glass was a popular medium for models and we might retrospectively discuss its advantages for that use, but it was far from the only material available. By the nineteenth century, many scientific models, ranging from medical learning tools to botanical specimens, had been created by artisans working in wax (Alberti 2009) and papier mâché (Märker 2005). Three-dimensional models in particular were indispensable to science because they offered representations without the color and form degradation of preserved specimens (de Chadarevian and Hopwood 2004). The Blaschkas' scientific contemporaries were particularly concerned about the preservation of soft-bodied sea organisms for study. In particular, the form and colors of many marine animals were thought to be destroyed by preserving agents. For their nineteenth-century users, glass models offered a stable—albeit rather fragile—pedagogical tool to teach species differences and the anatomy of sea creatures (Dyer 2008). The Blaschka models were trusted to stand in for organisms that the users might never have seen. The Blaschkas concentrated on glass, not because it was necessarily the best material for these models, although it could be argued that translucent organisms such as marine dwellers and botanical specimens might be particularly well represented by it. Instead, they chose this material for the simple reason that they were glass artisans who turned their skills toward a scientific subject.

Before the exclusive contract with Harvard's botanical division, the Blaschkas created glass models for sale through a variety of channels. In the United States, Ward's Natural Science catalogue presented around 700 models for sale to institutes or individuals. The first catalog described the models as "decorations for elegant rooms," but naturalists and institutions quickly became the primary buyers (Cornell University Library 2009; Reiling 2003; Arwas, Newell, and Sunderland Museum and Art Gallery 1997).

Cornell University was one such institutional buyer; its collection is of particular interest because it is divided among art and science entities. The Cornell collection is spread over four locations. There are three on-campus displays plus a fourth site at the Corning Museum of Glass in Corning, New York, where the remaining Cornell-owned models are in storage. The models on display in Corson-Mudd Hall, which hosts the Department of Ecology and Evolutionary Biology, and the Mann Library, which specializes in agriculture, life sciences and human ecology, have undergone restoration.* The models at the Johnson Museums of Art are largely one-piece models that did not require significant restoration. In all, these represented around 400 surviving models.[2]

The Blaschkas had long related their scientific modeling to artwork. Though this language of decoration drops out in later catalogs, the glassmakers continued to conceive of themselves in terms of inhabiting a combination of art and science worlds. It is telling that the family headstone in the cemetery in Dresden-Hosterwitz reads “Scientific Glass-Artists” (Dühning 2000). The Blaschkas’ engagement with the scientific community is not unique, however. The story of artists engaging with scientists and creating knowledge, particularly visual knowledge, is an old one—stretching back even before our current distinctions between artists and scientists. An excellent example is the intermingling of these two pursuits in the study of nature. The naturalist has a variety of skills to use to observe and display nature. Pamela Smith’s *The Body of the Artisan* accounts for the role of artists in relation to the new knowledge practices of science in the sixteenth and seventeenth centuries (2004). Londa Schiebinger’s work on anatomy has shown how gender politics were part of anatomical drawing, as well as how ideas about sex and marriage influenced Linnaeus’ categorization of the plant world and Erasmus Darwin’s depiction of a sex-based plant system in poetry (Schiebinger 1993). Crafts skills are necessary for representing and working with the new sciences, and the study of those skills reveal new forms of observation made possible by those skills (Lynch and Woolgar 1990). The difference between artist and artisan is itself fraught, because feminist scholarship (Gouma-Peterson and Matthews 1987; Hagaman 1990) has sought to revise art history to include what are sometimes known as “crafts,” usually women’s artisanal products. The Blaschkas are referred to in the contemporary period as artists, but they referred to themselves as artisans.

STS scholars have shown that artists in different forms have been present with and part of the project of natural philosophy and history dating back to those who are now considered major figures in both areas, such as Leonardo and Durer. Science studies scholars’ interests have not been limited to European art-science relations. Fa-ti Fan (2004) shows how art, science, and colonialism came together to serve the naturalists' needs. Fan traces the history of colonialists in Qing dynasty China, who were interested in sending home specimens and evidence of the animals, plants, and insects in China to be verified by the scientific community. These naturalists, who often lived in China for years, employed Chinese artists to create images for verification that were a distinctive mixture of the requirements of the colonist clients and the traditions of commercial art in China. These stable images carry information from abroad into British natural history discussions.

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*The digital collection of the Blaschkas models at Cornell University is available through the Mann Library online resource at https://digital.library.cornell.edu/collections/blaschka.

The Blaschka models performed a similar role. Like the images made by Chinese artists, they might be thought of as *immutable mobiles*. These immutable mobiles—Latour's stabilized representations that allow science to "act at a distance" (Latour 1987), page 229)— might be circulated to represent specimens not yet available in Britain. This serves to point out the role that artists have played not only in creating the means for scientific ideas to be circulated, but also in creating scientific knowledge directly. The Blaschkas' models are similar to Chinese drawings in that the models encode scientific ideas, but they are more than a means of codifying known principles into a model object. These artists went beyond copying scientific images* or recording scientific points in a disciplined fashion. Rather, the glass models necessarily involved the presentation of all kinds of information not available in the scientific literature or existing images. To create three-dimensional, detailed representational objects, the Blaschkas had to do their own studies and observations, and in doing so they were creating new ways of knowing sea creatures that would otherwise have been represented by flaccid specimens in jars or two-dimensional drawings. The knowledge that these artisans created was a method of displaying the salient features of marine life to the satisfaction of the scientific community.

The Blaschka models have been rhetorically and materially shaped by a variety of actors and institutions. At different times these models have been pedagogical objects, tools of naturalists, scientific models, historical artifacts, and art pieces. They have moved in and out of favor according to the politics surrounding them and the ways in which they have been coded in different contexts. By tracing how these objects have been displayed and talked about at Cornell, this episode exposes how objects such as the glass marine models can be made to function as part of the networks of art or science.

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*It is worth noting here that copying and replication are hardly unproblematic in themselves and often produce their own verification crises (Collins 1985).

METHOD

The story of how the Blaschka models were situated in both art and science contexts needs to be told through historical documents and by the people who continue to work with these models. I have interviewed people with many orientations toward the models: scientists, artists, glass restoration experts, amateurs interested in the Blaschkas and their work, journalists, glass scholars, and museum curators. I also consulted archives and records at the Johnson Museum of Art, the Cornell University Archives, and the Corning Museum of Glass's Rakow Research Library. I also made use of a number of records groups to understand the Blaschkas' interlocutors. I particularly made use of records and especially images pertaining to Ernest Haeckel held at the Royal Society and the Ernst-Haeckel-Haus in Jena. My research is also indebted to the work of the Dublin Blaschka Congress held in 2006 in conjunction with the exhibition *Crystal Creatures* at National Museum of Ireland – Natural History, which helped to orient me toward additional Blaschka models for comparison.

The Corning Museum of Glass in Corning, New York, maintains an archive of Blaschka sketches and much correspondence, which was helpful for assessing changes in drawing style and the relationship between other published works of the time and the drawings that the artists made based on them. The Cornell University archives and image collection were useful for sorting out the details of the models' acquisition and their physical movement around the campus.

My interviews on the science side began with Thomas Eisner, the professor who discovered the Cornell Blaschka models after they had been neglected for some years. I interviewed Eisner in the spring of 2008, and he introduced me soon after to Drew Harvell, a professor of ecology and evolutionary biology and current curator of the collection. By coincidence, during the course of my research, the Mann Library collection opened at Cornell, and Harvell gave a talk in which he acknowledged the value that scientists placed on the Blaschka collection today.[3] Harvell published *A Sea of Glass* (2016), which uses the glass models and Harvell's diving experiences to make the case for ocean conservation; he was also the scientific counselor on the short film *Fragile Legacy* (2015). Eveline Ferretti at Mann Library provided useful documents about the Mann collection and the way in which it has been advertised to increase interest in the exhibit.

In January 2010, I began a correspondence with and subsequently interviewed William Warmus, a glass expert who extensively photographed and wrote about the Cornell Blaschka collection for *Glass* magazine. I also interviewed Elizabeth Brill, the glass and marine expert who was working to restore the collection and who offered insights about her restoration techniques. Brill has worked and consulted on several other Blaschka model restoration projects, including the marine animals in Harvard's possession, and has written a book on them from a conservator's viewpoint (2016). At the Johnson Museum of Art, Associate Curator Andrew Weislogel provided the museum's perspective as well as his own observations. Beginning in spring 2010, Weislogel helped me look for documentation relevant to the objects on loan, traced the path that the objects followed into the Johnson Museum's possession, and assisted in securing important interviews with the Museum's registrar, Matthew Conway, and then-director Frank Robinson.

THE NATURAL HISTORY TRADITION

The Blaschkas described themselves as "natural history artisans," an expression useful to contemporary actors in setting up their work as an interdisciplinary practice. To represent, teach, and display difficult-to-preserve specimens, institutions undertook the systematic collection of taxidermy and scientific drawings. As modern museums were established in the nineteenth century, they became places for research and displays for the public as well as for students, and the Blaschkas created objects for collections (Schultes, Davis, and Burger 1992). Popular fascination with sea creatures, especially jellyfish and anemones, opened a space for them to provide a scientific tool that would enhance both their standard of living and their reputations. Natural history was in vogue at the time, and the father–son team obliged the moment with work that satisfied the demand for realistic models, as judged by the standards of the day. They navigated the networks of science while maintaining a claim to be glassworkers in the network of the traditional craft (Rossi-Wilcox et al. 2007).

In the 1880s, Rudolf joined Leopold in creating models. Rudolf studied anatomy, botany, and zoology at the Dresden Imperial Academy. His second formal training, which followed his familial apprenticeship in glassmaking, serves as another point of departure in making the case that the Blaschkas' work surpasses either discipline alone. His father's training had been oriented toward the family craft of glass, and Rudolf worked with his father in making floral jewelry, but he always maintained an interest in the natural world and created many sketches. Rudolf's formal natural history training, however, afforded the pair forays into the science of the day (Rossi-Wilcox et al. 2007). The Blaschkas used the illustrations from Phillip Gosse's *A Naturalist's Rambles on the Devonshire Coast* (1854) and *Actinologia Britannica: A History of British Sea Anemones and Corals* (1860) as the basis for additional sketches and, eventually, glass models (Sigwart 2008; Schultes, Davis, and Burger 1992).[4] Without direct access to the marine creatures, the pair studied the drawings as if they were the organisms themselves. They created drawings from other drawings and then completed their models. The Blaschkas also corresponded with Haeckel (1834–1919), a leading marine naturalist and proponent of Darwin's theories who sent the artisans scientific drawings and atlases, including some of his own work (Haeckel 1879).[5]

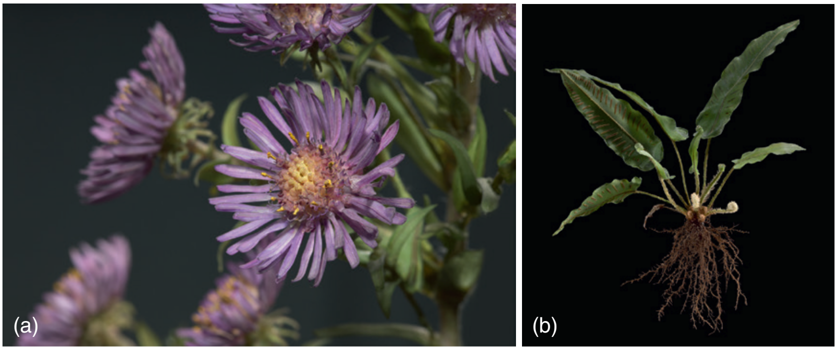
Early in life, Leopold was prescribed a sea voyage for his health. He traveled to the United States on a ship that became becalmed and was stuck at sea for some days before it reached its destination (Rossi-Wilcox 2008). Scholars often credit his study of sea life during the voyage as the starting point for his excitement about natural history (Rossi-Wilcox et al. 2007). Also prominent in these accounts, probably because of the emphasis that the artists themselves placed on artisanal bloodlines, are references to the Blaschka family's originating in Aicha, Northern Bohemia, and relocating to Hosterwitz, Germany. Later in his career, Leopold would claim that his family members were famous glassmakers in Bohemia.

The glass models quickly proved popular, and the glassmakers received institutional support. Between 1860 and 1862, Prince Camille de Rohan commissioned and exhibited more than 100 models of orchids, which he displayed on two artificial tree trunks in his palace in Prague. By 1863, Ludwig Reichenbach, the director of the Dresden botanical gardens and natural history museum, had taken an interest in Leopold's work.

Reichenbach's connections and access to specimens proved important for the Blaschkas' career. The first zoological models to be shown were representations of the British sea anemones and corals (Reiling 2003). Reichenbach exhibited them in dry aquariums in the Dresden museum, suggesting that the father–son team were modeling objects to look as if they were living underwater. After their move to Hosterwitz, the team became increasingly well-known and shipped models around the world (Rossi-Wilcox 2008; Rossi-Wilcox et al. 2007; Rossi-Wilcox, Reiling, and Bisaga 2003).

The Blaschkas practiced a distinctly nineteenth century style of scientific representation, a fact that has lent itself at different moments to different assessments. At times, the models have been discussed as an important part of science history; at others, they were perceived in science circles as outmoded and of little value. From specimens that they were sent and from the atlases and drawings of naturalists, the Blaschkas created preparatory drawings and finally glass models. Like many nineteenth century elites, they kept an aquarium and, eventually, a large garden with many North American plants, which they used to create models for natural history collections. Additionally, Rudolf took several science institution sponsored field trips. Despite his father's initial objections (Americans "eat too much ice" and "are all in a great hurry"), Rudolf traveled to the United States and the Caribbean (Rossi-Wilcox 2008), including a particularly fruitful trip that included a visit to Jamaica in 1892. On these trips, Rudolf created drawings that the pair later rendered into glass.

Rudolf's trips and the guides and graduate students who accompanied him were arranged by Professor Goodale, who became the first director of Harvard University's Botanical Museum in 1879. Goodale later facilitated the formation of the Glass Flowers collection through lobbying his colleagues, negotiating with the patrons of the collection, Mary L. Ware and her mother, and providing specimens and images for the glassmakers to



2.3 *Symphyotrichum novae-angliae* (New England aster) (a), Leopold and Rudolf Blaschka, 1893. *Source:*The Ware Collection of Blaschka Glass Models of Plants, Harvard University Herbaria/Harvard Museum of Natural History © President and Fellows of Harvard College. (b) *Asplenium scolopendrium var. americanum* (Hart's tongue fern), Rudolf Blaschka, 1903. *Source:* The Ware Collection of Blaschka Glass Models of Plants, Harvard University Herbaria/Harvard Museum of Natural History © President and Fellows of Harvard College.

use as a basis for their models. Goodale first came into contact with their work in Harvard Museum of Comparative Zoology, which had a set of the glass marine invertebrates.

During Rudolf's 1895 trip to the United States, Leopold died. After his father's death, Rudolf continued to work by himself. When Rudolf retired from glassmaking in 1936, he was nearly 80 years old and had created more than 3000 models for the Harvard collection alone. Thousands more had been made for universities, museums, and naturalists worldwide (figure 2.3).

DISCOVERY AT CORNELL

Cornell University's glass model collection began with the interest of Professor Comstock of the Department of Entomology and Invertebrate Zoology and A. D. White, the university's co-founder and first president. In 1882, White commissioned a set of marine invertebrates from Ward's Natural Science Establishment in Rochester, New York (Warmus 2001). Ward's carried a catalogue of the Blaschka models, which were each made to order, because the artisans required payment for the models and shipping costs prior to beginning their fabrication (Dyer 2008). In the *Comstocks of Cornell* (1953), Anna Botsford Comstock wrote: "[In] autumn [1882] . . . the President became enthusiastic over the beautiful models of invertebrates, made in glass. . . . President White went with Mr. Comstock to Rochester to select and buy the glass models." It is interesting that Anna Comstock notes their aesthetic qualities ("beautiful models") as a reason for White's interest.

In all, more than 700 models covering a large range of marine species were created for Cornell University. Of the originals, 570 have survived, although in recent years fewer than 200 have been on display (Mann Library 2002). They are made primarily of glass, but some glass sections are put together with wire and glue. Some are painted, whereas others are made from colored glass. The painted models are particularly vulnerable because they were coated in an organic material to enable the paint to stick. This coating tends to break apart, causing paint flecking, particularly at the edges of the pieces. The models have been further degraded by variation in the materials that make them up because they contract and expand with the temperature and humidity at different rates.*

The Cornell models eventually ceased to be used for teaching and were placed in storage. In the fall of 1957, they were rediscovered by Professor Thomas Eisner and his graduate student, Roger Payne (Warmus 2001). Eisner was beginning a career in the life sciences at Cornell that would span five decades and be distinguished by the discovery of chemical signals exchanged between insects. According to Eisner, the Blaschka models were barely visible through the windows of a wooden cabinet in the hallway of Roberts Hall. Eisner inquired about them, but the key was lost. Using a paper clip, Payne managed to open the locked cabinet. Inside they found the "incredible" models.†

What happened after the models became disused is difficult to trace. It seems likely that the models initially joined the university collections. The records of the university collections are now held by the Johnson

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*The condition of the models and plans for their restoration were discussed by the author with Elizabeth Brill in a series of phone interviews and email exchanges between 2008 and 2010.

†This narrative was recounted to the author during a 2008 interview with Professor Tom Eisner.

Museum of Art, but because many items were grandfathered into the museum's registry, it is not possible to verify that the models were among those items. During building moves in the 1940s, it seems likely that the models made their way to the cases where Eisner found them in 1957; the university collections had been divided up among departments and new display collections, including the art museum, a mineral display, and an anthropological collection. It is worth noting that the Johnson Museum of Art was only completed in its current form in 1973. Although the museum director recalled that the models were initially brought over on loan by Eisner, the next historical records are for their insurance in the early 1990s.

In interviews, Eisner was able to fill in many of the gaps in the records. When he found the models, Eisner was not aware that they had been made by the Blaschkas, although he knew about Harvard's botanical models. He was, however, so impressed with them that he began to investigate how they might be better preserved, because all were dusty and many were damaged. In 1964, when he published his first book *Animal Adaptation* with Allison Burnett, Eisner reproduced several photographs that he had taken of the glass models to illustrate specific points about the lugworm, Sabella, and squid. Unable to interest members of the science community at Cornell or the then–Dean of Agriculture Charles Palm in the models, Eisner contacted the Corning Museum of Glass. The museum staff identified the models as the Blaschkas' and were very keen to store them. Thus, the models were relocated some two hours away in Corning.* Dr. Elizabeth Brill, a marine biologist and glass restoration expert, was enlisted to restore a number of the models now on display at Cornell. Hoping to bring all the models back to campus, the current curator of the collection, Drew Harvell, worked to raise funds for their restoration and display, partly through making use of the collection for a current scientific project to identify and track the living marine creatures that inspired the models.

The collection at Cornell is currently divided among four sites, creating a contrast between their display in art and science contexts. Most of Cornell's models continue to be in storage at the Corning Museum of Glass. The first place where the models were shown on campus after their rediscovery was the Johnson Museum of Art. The museum had the resources to place a small group of objects on display. As funds became available, a larger display was added across campus in Corson-Mudd Hall, where the Department of Ecology and Evolutionary Biology is located. In 2010, the Mann Library opened the third public display of Cornell's Blaschka models with an inaugural lecture by Harvell.

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*These details were recounted to the author in a 2008 interview with Professor Tom Eisner.

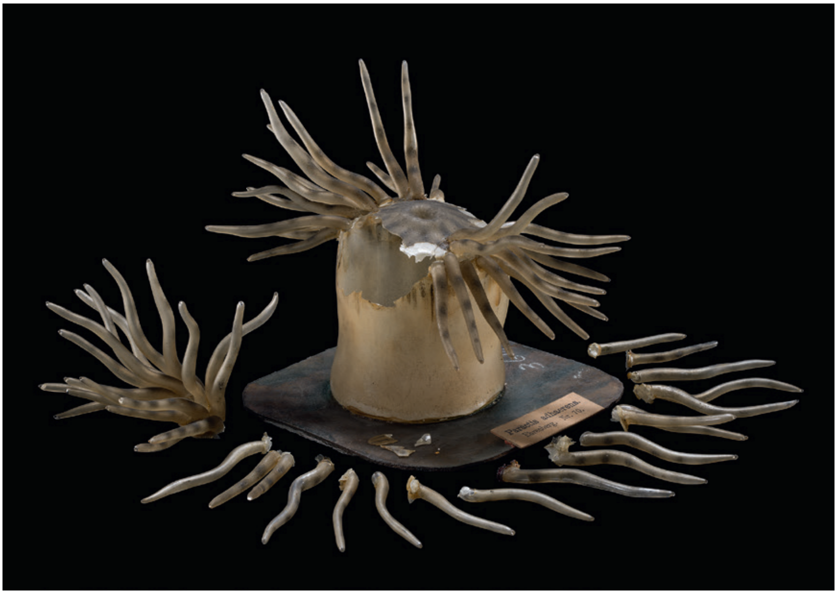
On the surface, it may seem odd to break up a collection that surely drew at least some of its power from comparative studies. This, however, is a story about how people worked to align resources to keep the models in circulation. The need to find resources to preserve the models constrained decisions on where and how to display them. Considering where the models were displayed and how they were defined as being important for art and for science is vital to understanding them. Actors crafted descriptions and definitions around the models, a task that revolved around making available resources relevant to the models and vice versa. The division of the collections and reorganization around new principles in several different locations do raise questions, however, about what the models represent in their new contexts.

The Johnson Museum glass model collection is a selection of objects on loan from the primary collection, an arrangement that is renewed annually with Drew Harvell, the primary curator of the collection. Although the particulars of the origin of the loan are unclear, Eisner was extensively involved with the Johnson Museum. For example, he donated an early photograph that he had made of an insect's-eye view of the target shapes that insects see on flowers—shapes that are not visible to the human eye—and he helped the curators identify the insects that artist Otto Marseus van Shrieck included in his painting *A Forest Floor Still Life with Various Fungi, Thistles, an Aspic Viper, Etc.*. It is likely that Eisner's connections to the museum, both as a contributor and as an information resource, facilitated the loan of the original small group of Blaschka models to the museum.

The glass models are displayed on the second floor of the museum in an unassuming case at the top of the stairs. They are surrounded by American paintings, including Andy Warhol's *Most Wanted Men No. 1,* *John M.* (1964) and Lee Bontecou's *Flit* (1959). The models are housed in a glass case the size and height of a desk, with a light background for the display surface. Because of the properties of glass, namely its ability to reflect, refract, and transmit light, the background of the models has a considerable impact on the impression they give in person or in photographs.. The translucent and layered colors present in some marine life and botanical specimens is realized through the medium, but the backgrounds have an outsized impact on our eyes' ability to interpret those details. William Warmus photographed Cornell's collection in the early 2000s and suggested that a dark background would allow the models to be seen more clearly (Warmus 2001). Indeed, most of his photos feature a black or nearly black field.[6] However, the light background is standard for the museum's display cases. This does have the effect of standardizing the objects by treating them like other artworks on display but, in the opinion of some viewers, may obscure vision.

The museum display employs only the original scientific labels attached to the models. The related curatorial text describes them primarily in terms of their historical and craft value. It has not been possible to learn what criteria were used to select models on loan to the Johnson Museum, but the absence of, for example, jellyfish, with their delicate individual glass tentacles, suggests that the ability to move the models safely was a key consideration. The models themselves are not laid out in lines but placed around the case in a relative balance of sizes and forms. It appears that these models were moved to the art museum with minimal restoration, so part of the choice of which would be displayed was simply a reflection of their relative condition. Because the creatures that were pieced together with wire and animal glues were particularly fragile, it seems likely that those models would have required more restoration and, therefore, not been available for immediate display. This would explain the fact that the more intricate models that were restored later are exhibited in science venues (figure 2.4).

In the Johnson museum display, only one of the original name cards on the specimens has been preserved. Relative to the rest of the collection, the individual pieces at the museum are, on the whole, smaller than those in either Corson-Mudd Hall or Mann Library. The type of model on display is likely the result of concerns about moving the objects, but the

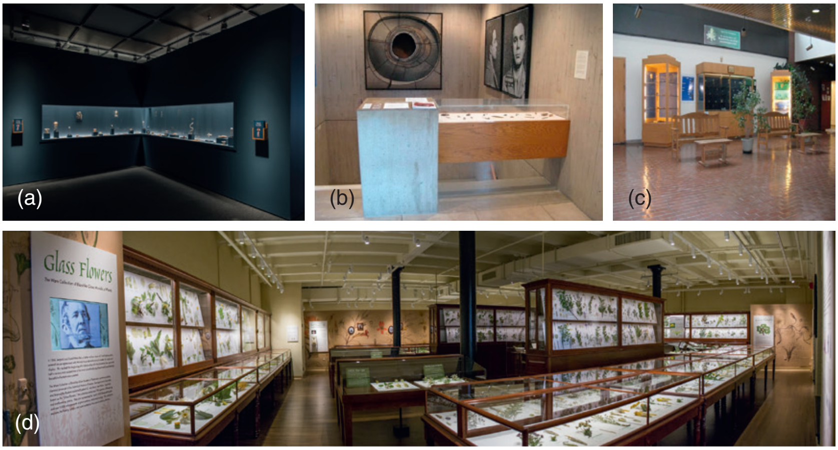


2.4 Leopold and Rudolf Blaschka: *Entacmaea quadricolor* (1885). Glass model produced a s *Paractis adhaerens*. CMOG L.17.3.63–366. Lent by Cornell University, Department of Ecology and Evolutionary Biology. *Source:* Image licensed by The Corning Museum of Glass, Corning, NY (www.cmog.org) under CC BY 4.0.

effect is that the models appear rather more mundane than the ones in the more theatrically dark backgrounds used in the science displays and depicted in Warmus's photographs.

The accompanying curatorial text is written in a sparse factual style. It describes the origins of these particular models, including their rediscovery by Eisner. The accompanying wall text celebrates the objects as being "originally intended as models for biological studies, but [which] have now also become acknowledged as artistic productions." This way of talking about these objects in their art context is similar to the way in which Wieslogel, a curator of earlier European and American Art, discusses the museum's interest in the objects in an interview: as examples of craft glass production with historical value stemming in part from the university's role in investing in them. From the art curator's perspective, the process of creating the models and situating them in an institution is of more interest than, for example, an aesthetic or style concern with the models themselves. Wieslogel also echoes Eisner in indicating that part of the value of the objects to the art network stems from their value in the scientific community (Weislogel 2010).

The presentation of the objects in the Johnson Museum poses a stark contrast to attempts elsewhere to attract new audiences to science by displaying spectacular contemporary scientific images in art museums (figure 2.5). The science evoked in the display is of historical importance to the university and beyond, with the Glass Flowers invoked in display captions, popular culture, and literature. The Johnson Museum display can be usefully contrasted to the collection located in the atrium of Corson-Mudd Hall, where many more models are located. The display is flanked by a saltwater coral aquarium and a collection of taxidermy birds. The taxidermy and living specimens on either side lend an authentic air of the past, alluding to the models' original science context. These displays offer a sample of the different ways in which science has approached stabilizing specimens from the natural world. Also prominent is a display



2.5 The Corning Museum of Glass, *Fragile Legacy: The Marine Invertebrate Glass Models of Leopold and Rudolf Blaschka* (2016) (a). *Source:* Image licensed by The Corning Museum of Glass, Corning, NY (www.cmog.org) under CC BY-NC-SA 4.0. (b) Herbert F. Johnson Museum of Art, Cornell University Blaschka Glass Models Display (2012). Corson Mudd Hall, Cornell University, Blaschka Glass Models Display. (c) Glass Flowers exhibit panorama. *Source:* The Ware Collection of Blaschka Glass Models of Plants Harvard University Herbaria/Harvard Museum of Natural History © President and Fellows of Harvard College.

advertising the university's marine biology study abroad program, yet another way other than aquariums, stuffed birds, and glass models, through which students might encounter biology and ecology.

The Corson-Mudd models are displayed along with a descriptive poster, including images of Blaschka sketches. Two multishelved cases make it possible to view the models from different angles; they flank a larger central case. Perhaps meant to evoke the watery environment, the clear glass shelves enable viewers to see through some of the translucent models, making it hard to pick out details. The third, longer case is in the center and has a dark blue background that offers better viewing. Because not all the university's models have been restored, what we have on display are selections. In the left-hand case, taxonomically related models are grouped together. The right-hand case has a backing meant to represent ecosystems.

Instead of being grouped by taxonomic relationship, the models are grouped in diorama style by the ecosystem in which they appear. The background consists of photographic laminates, which adhere much like an aquarium backing and suggest additional information about the ecosystems in which the organism would appear. The groupings in the Corson-Mudd atrium form a sharp contrast to the small display in the Johnson Museum. In Corson-Mudd Hall, the models are meant to be viewed in groups, either by species type or by shared ecology. The models have been enrolled to depict changes in methods for studying the natural world. The arrangement of these pieces is meant to emphasize the "correct" way to see the models, as learning tools that are both identifiable and distinguishable from one another. The result is a coding of the objects as scientifically valuable in terms of clustering similar specimens and as species that share ecosystems.

The Mann Library offers two ways to experience the models: cases located in the stacks of the library and an online catalog and explanation of the models. The two cases include a range of specimens, similar to those in Corson-Mudd Hall. The websites function as a catalog for the exhibit with a list of all the models in storage and on display as well as commentary by experts. The value of the models offered on the Mann Library Blaschkas collection website as much about conservation of the oceans as conservation of the glass: "As earth's oceans are degraded, as their numbers of endangered or threatened inhabitants grows, these nineteenth-century teaching devices could conceivably furnish exquisitely rendered records of what has been lost for students of the 22nd century." This move from rather basic display cases in a science building to a more prominent place on campus as part of the Mann Library's exhibits took place in large part due to the efforts of Harvell. She used the models to argue for ocean conservation to protect marine biodiversity. Harvell and her students used the models as a guide to search out the specimens that the Blaschkas had modeled and created a survey using the list of models as a guide. Her findings showed that the sea organisms that the Blaschkas recorded in glass are largely still extant, but their existence is under severe danger from overfishing and pollution, so they tend to be most plentiful in ocean reserves.

At the opening of the Mann Library display, Harvell described the models as tools for future conservation research but also repeatedly invoked their beauty (Harvell 2010). Although it might be argued that for naturalists, beauty can be taken as a scientific category, today we primarily associate invocations of beauty by scientists with an attempt to draw in the public. Accordingly, the value for Harvell seems to be in these objects' ability to reach new audiences and to be translated into a marine conservation interest. In short, their value is not simply in being scientific objects but in being beautiful objects with broader appeal. It is something beyond the scientific that makes them important. The extension of value created by evoking the criterion of beauty, assumed to be outside the domain of science, is the equivalent of the work done by the curatorial text in the Johnson Museum of Art. The text connects the models to the chronicle of the university's research and to the history of science. The object's value in its respective networks is predicated on its value in the adjacent network.

These three different displays are examples of the way in which specific actors involved in the networks of science and art have enrolled the models for their own purposes. The museum's display emphasizes the craft aspect of these pieces: they are celebrated in relation to their scientific roots and the craft techniques necessary to produce accurate models (Corning Museum of Glass 2002). The minimalist display case couches the models as art objects, like the others in the museum. Viewers are perhaps meant to understand that art and its techniques penetrate even their presumed opposite: science. The models are made different and their meanings potentially changed by their context. Whereas the art-contextualized models are placed to be valuable as individuals, the science-contextualized models are to be prized as a group. In both cases, information about their art and their science meanings is offered. The interest in these objects by several parties at Cornell University made logical the division of the collection and its preservation by different hands, furthering their value in communities of art and science.

TACIT KNOWLEDGE AND BLOODLINES

In both early and more recent accounts, the Blaschkas were said to have nearly superhuman skill with glass. According to their own testimony, their virtuosity stemmed from their family's history of glassmaking. The idea that their abilities were somehow passed through bloodline was promoted mainly by Leopold. He described his reasons for believing that no one else would be able to duplicate their work in a letter to Mary Lee Ware in 1889: "Many people think that we have some secret apparatus by which we can squeeze glass suddenly into these forms, but it is not so. We have tact. My son Rudolf has more than I have, because he is my son, and tact increases in every generation. The only way to become a glass modeler [sic] of skill, I have often said to people, is to get a good great-grandfather who loved glass; then he is to have a son with like tastes; he is to be your grandfather. He in turn will have a son who must, as your father, be passionately fond of glass. You, as his son, can then try your hand, and it is your own fault if you do not succeed. But, if you do not have such ancestors, it is not your fault. My grandfather was the most widely known glassworker in Bohemia" (Ware 1961).

The younger Blaschka's keenness to invoke the family's artisanal heritage served a specific type of cult of the genius, and it certainly would not have hurt sales to imply how rare, specific, and unteachable their skills were. Emphasis on the family of glassmakers can be seen to follow ideas about the cult of the genius and ideas about traditional craftsmanship and how artisanal skills can follow family lines. Family lines become conduits for tacit knowledge. The narrative at once emphasizes the lack of magic in their process, moving toward a science of glass, and simultaneously raises the idea of inherited skills as an important aspect of modeling. It is frequently mentioned that the family had roots in Venice, a city storied for its glassworks. Though he apprenticed as a goldsmith and as a gem cutter during his school years, Leopold in most accounts followed his family into the craft. His early work in glass included "ornaments, jewelry, test tubes and glass eyes (for people, and taxidermists' animals)" (CoBiD 2005). The supposed heritability of glassworking traits might also have appealed to scientists working with the new theories of evolution.

Interestingly, Leopold's reference to "tact," a kind of specialized knowledge that he could not describe to Ware, anticipates the modern understanding of tacit knowledge as popularized by science studies (Collins 2001; Lynch 2002). The glassmaker did not suggest that a specific technology was involved in the creation of these models, implying that skill is firmly vested in him and his son as makers. In this way, Leopold protected his craft, doubtless to make a case for continued patronage. Certainly, modern biographies and exhibitions hew to the view that the Blaschkas' working methods were secret or unknown. We see the men as insiders in the scientific enterprise, even as their skills derived from artisanal practice situated *outside* the project of natural history. Today, interpreters draw on the contradictory threads of this self-fashioned history to frame the models as both art and science.

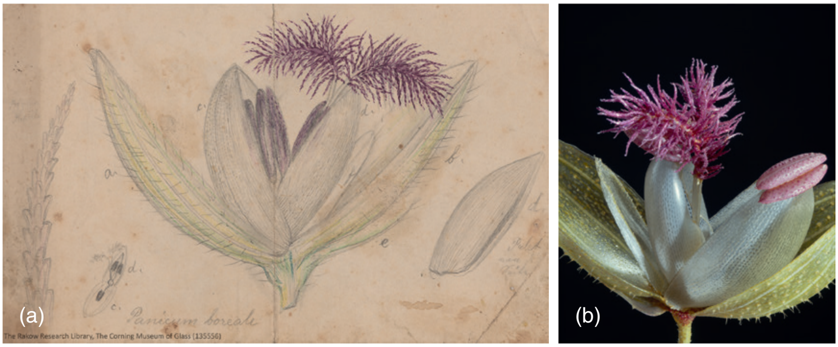
MODELING REALITIES

To Blaschka expert Henri Reiling, a "model represents something, which it is essentially not" (2003), and scientific models postulate realities. For the Blaschkas, the task was to turn glass and glue, things that are essentially not a jellyfish or a radiolarian, into things that naturalists could accept as being useful in knowing living things. There were ways in which glass models could even be considered superior to organisms. Reiling (2003) calls the models "better than nature," noting that they are "forever available." Specimens preserved in alcohol were understood to be poor at reflecting original shapes and colors. Scientific drawings, and eventually photographs, were two-dimensional. All these potential representations reflected different aspects of reality, but glass stabilized the character of evanescent organisms.

The other unique aspect of glass was that it imparted lifelike qualities in models, so much so that some Blaschka artifacts can often be mistaken for the real thing. As Lorraine Daston (2007) notes, this is especially true of Harvard's Glass Flowers, which have generated intense popular interest for their powerful psychological effect: "Although [the models] are representations themselves, they defy representation. A photograph of the glass model of a daylily or a strawberry plant looks exactly like a photograph of the daylily or strawberry plant in your garden . . . [i]t is the wonder of the copy that itself cannot be copied, which somehow is more authentic than the original" (page 254).

For Daston, the wonderment derives from that which cannot easily be represented, because representation tends to reflect on the organism rather than on the model. A photograph of the Glass Flowers looks more like a photographic representation of real flowers than a photographic representation of model flowers. This disorienting effect is especially profound in the case of Rudolf's model of a diseased apple, photographs of which Lorraine Daston has noted are difficult if not impossible to distinguish from a photograph of an actual specimen. What is being represented in images of this work is intriguingly confusing because viewers are aware that they are experiencing an image but are unsure whether what they are seeing is an artifact or an organism.

Daston does not address the Blaschkas' earlier works, most of which do not seem to possess this lifelike quality and indeed display some features that we may associate with artistic expression in their era. Certainly, the lighting and composition of photographs play a role in our ability to understand them as models or specimens. For example, the solid black background makes it easy to distinguish the parts of the model but difficult to understand size and positioning, which heightens the effect that Daston describes. Other photographs, particularly those in which the models are shown in glass vessels, do not tend toward this effect, and the reflections of the glass against the vessel tend to make the medium more obvious. Contrasting the later models with earlier Leopold specimens, the effect is stark. Few contemporary viewers would mistake this model for its specimen.


(a)
Panicum boreale
The Rakow Research Library, The Corning Museum of Glass (135556)
(b)

2.6 Rudolf Blaschka. *Panicum boreale* (Northern panicgrass) (a). Original art/scientific illustration, preparatory reference drawing, pencil and colored pencil on paper; 13 x 21 cm. 1986–1923. *Source:* Rakow Research Library Special Collections, Digitized by Harvard Museum of Natural History 2006. (b) *Panicum boreale* (Northern panicgrass). Rudolf Blaschka, 1923. *Source:* The Ware Collection of Blaschka Glass Models of Plants. Harvard University Herbaria/Harvard Museum of Natural History © President and Fellows of Harvard College.

SCIENCE, STYLE, AND CONTEXT

To the Blaschkas, scientists were both their market and the best source of information to create their business. To recreate a model from life, they had little choice but to resort to the scientific illustrations and descriptions produced by the zoologists and biologists of their day. In short, observation and imagination were crucially informed by the trained seeing of others. In planning their work, the glassmakers drew illustrations based on scientific plates and sometimes directly copied them. The Rakow Library at the Corning Museum of Glass houses hundreds of drawings made by the Blaschkas, particularly from their early period. Some of the drawings are precise copies from atlases, down to the pen strokes and colors (figure 2.6).

According to Reiling (2003), approximately 300 models were created from scientific images in nearly 70 publications. Figure 2.7(a) is an illustration from Gosse's *Actinologia Britannica*. The style and colors in the model in part (b) are based on the anemone in the bottom right-hand corner of Gosse's plate (figure 2.7). Considerable judgment was required in depicting a type rather than a single specimen. Daston and Galison's concept of truth-to-nature (2007) suggests that there cannot be a real referent for any representation because elimination from the original is

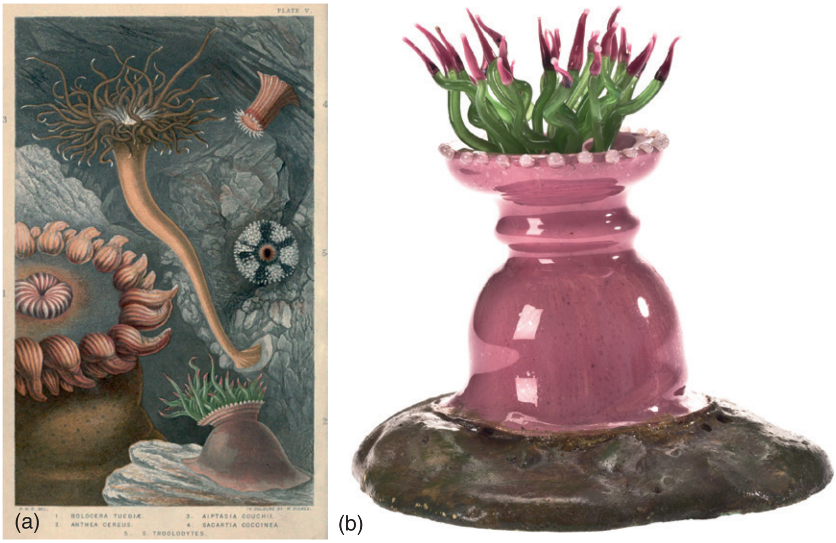
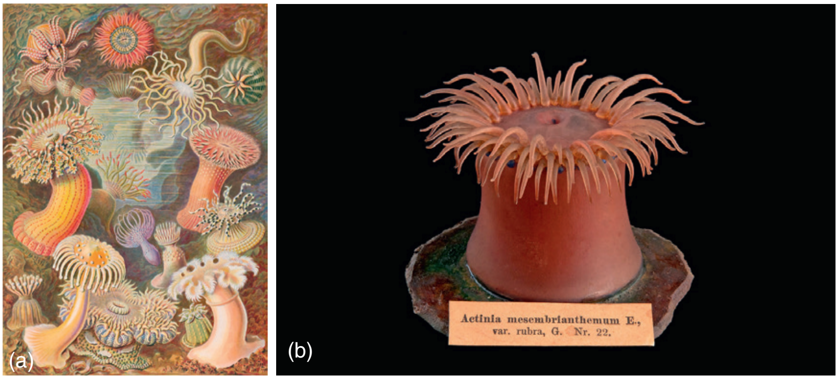


PLATE V.
1. BOLOCERA TUEDIÆ.
2. ANTHEA CEREUS.
3. AIPTASIA COUCHII.
4. SAGARTIA COCCINEA.
5. S. TROGLODYTES.
(a)
(b)

2.7 Lithographic print by William Dickes based on an original watercolor by Philip Henry Gosse, featured in the latter's *Actinologia Britannica: A History of the British Sea-Anemones and Corals (a)*. Van Voorst (London) 1860, Plate V. *Source*: Smithsonian Libraries, via Internet Archive. (b) Snakelocks sea anemone. *Anemonia viridis* (Forskål, 1775). Glass model produced as *Anthea cereus* (Ellis) by Leopold and Rudolph Blaschka, Dresden, Germany, 1863–1890. *Source:* Photograph © National Museums Scotland.

the essence of a model. Without question, the Blaschkas' most important scientific interlocutor was Haeckel. In 1877, the glassmakers met the prominent natural scientist and the author of *Art Forms in Nature* at his marine research station in Jena (Moses 2008). They studied Haeckel's scientific descriptions and copied many of his drawings to use as preparatory materials, sometimes element for element. Figure 2.8 shows two Blaschka models and the Haeckel drawings on which they were based. In turn, Haeckel corresponded with the Blaschkas about specific specimens, notably the hydras. To be considered realistic at this time, the models needed to exhibit not only an adherence to contemporary scientific norms but also what, in the vein of "truth-to-nature," could be called "truth-to-culture"; that is, the style needed to appear plausibly real to viewers in a relevant context. Like Haeckel's drawings, the Blaschka models had to represent the essential qualities of particular organisms or emphasize specific features to enable identification (figure 2.8).

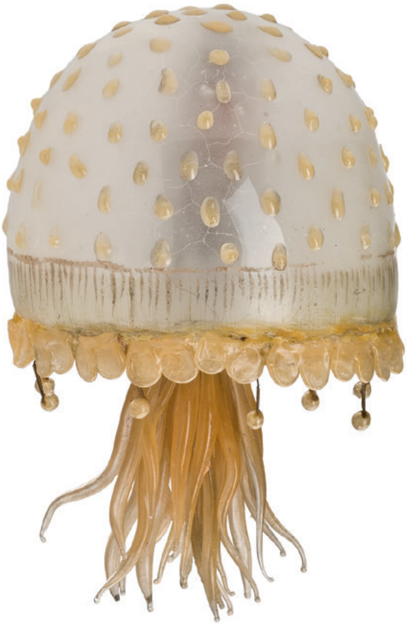


2.8 (a) Ernst Haeckel. *Kunstformen der Natur* (1904), Plate 49, *Actiniae*. *Actinia equina* (beadlet anemone). Glass model produced as *Actinia mesembryanthemum*. *Source:* Cornell Collection of Blaschka Invertebrate Models. Photographer: Kent Loeffler. © Image: Cornell University/Courtesy of the Cornell Collection of Blaschka Invertebrate Models. Used by permission. (b) *Anemonia sulcate* (snakelocks anemone). Glass model produced as *Anthea cereus*. *Source:* Cornell Collection of Blaschka Invertebrate Models. Photographer: Kent Loeffler. © Image: Cornell University/Courtesy of the Cornell Collection of Blaschka Invertebrate Models. Used by permission. Here is the model specific link: https://digital.library.cornell.edu/catalog/ss:20107752.

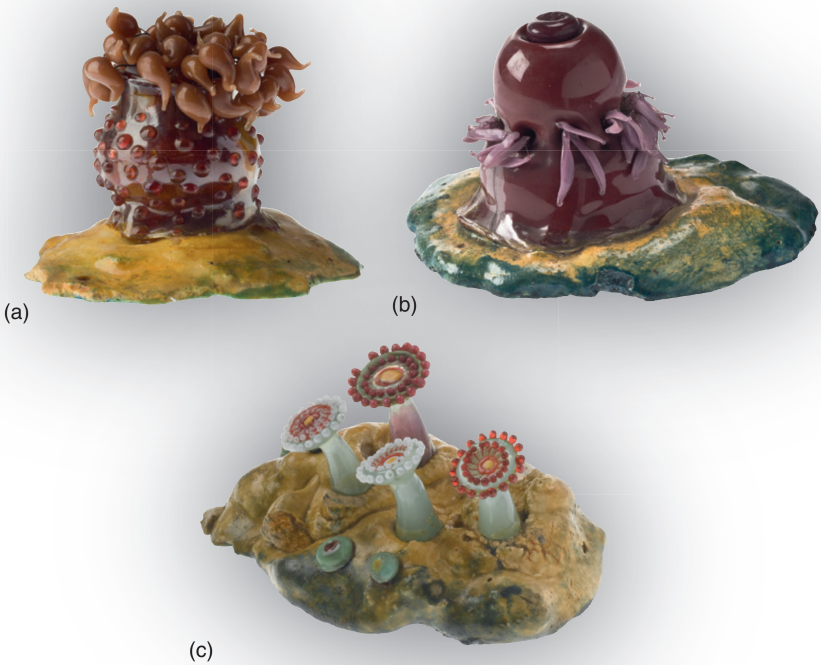
The models also had to domesticate unfamiliar organisms for an audience eager to learn about the mysterious ocean realm. To do that, they needed to code these life forms in a recognizable style (Haeckel et al. 1998). For Haeckel's audiences, that style was Art Nouveau, an emerging international art movement that incorporated elements of what was then known as "oriental" style, primarily around Japanese themes (Greenhalgh 2000). Haeckel himself played a role in its incarnation, particularly in developing its architectural style (Haeckel et al. 1998). Art nouveau was preoccupied with organic aesthetics. Formally, the style was characterized by whiplash lines, particular associated with "natural" or "organic" forms and symmetry, both across the page and at the level of detail. Marine creatures made excellent Art Nouveau subjects, as did trees and floral motifs, because they lent themselves to the emphasis on symmetry while continuing to be recognizable. Haeckel sought to ground unfamiliar life forms in a visual language that his readers could comprehend, and the dual quality of Art Nouveau in rendering specimens interpretable at the cutting edge of representation made it an appealing way to depict the natural world. It made Haeckel's work approachable to generalist readers of the time and supported his beliefs in the beauty and variety of nature.

The Blaschkas' craft was crucially informed by Haeckel, among other scientists of the time. As Reiling (2003) put it, "If [the] Blaschkas' glass models are presented in the context of their contemporary decorative arts, they presumably would be recognized in retrospect as related to expressions of Jugendstil and Art Nouveau, a relationship that already has been obvious for the knowledgeable eye" (235). Art Nouveau's emphasis on symmetry carried through the plates of Haeckel's *Art Forms in Nature* and into the glass models. A key scientific standard of representation of the time, however, was the *fanciful* quality of sea life. Like Haeckel, the Blaschkas responded by producing models evocative of the exotic (figures 2.9 to 2.11).

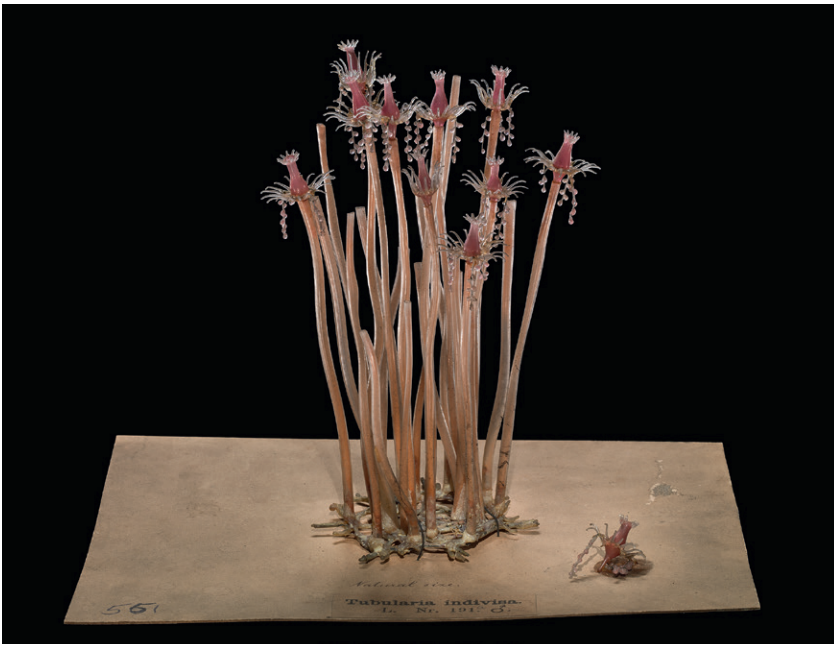
Many of the Blaschka models, especially the earlier ones, were based on reimagined studies of images created by naturalists such as Haeckel.



2.9 *Melicertum perla* (thecate hydroid). Glass model by Leopold and Rudolph Blaschka, Dresden, Germany, 1863–1890. *Source:* Photograph © National Museums Scotland.



2.10 *Tealia digitata* (marigold wartlet sea anemone) (a). Glass model by Leopold Blaschka, Dresden, Germany, 1866. *Source:* Photograph © National Museums Scotland. (b) Sea anemone. *Actinia concentrica*. Glass model by Leopold Blaschka, Dresden, Germany, 1866. *Source:* Photograph © National Museums Scotland. (c) *Corynactis viridis* (globehorn). Glass model by Leopold Blaschka, Dresden, Germany, 1866. *Source:* Photograph © National Museums Scotland.



2.11 Leopold and Rudolf Blaschka. *Tubularia indivisa* (1885). CMOG L.17.3.63–551. Lent by Cornell University, Department of Ecology and Evolutionary Biology. *Source:* Image licensed by The Corning Museum of Glass, Corning, NY (www.cmog.org) under CC BY 4.0.

However, the later works look markedly different. Aesthetic values from the Art Nouveau period (1890–1905) were eventually discarded, to be replaced by a different style informed by the scientific community's preferences for precision instrumentation. As the scientific eye became more accustomed to understanding organisms through photography, the Blaschkas built models reflecting those sensibilities. The new "correct" model (that is, the one preferred by science) had to look realistic, and that necessarily involved the use of a style that the buyers would recognize as such (Abell 2007; Gombrich 1987, 205).

In part, the stylistic shift was conditioned by changing scientific interests. In their later period, when Harvard was their sole customer and plant identification was no longer primarily the focus of botanical research, the Blaschkas found it necessary to meet demands in a variety of ways, including the creation of life cycle models, notably the fern reproductive cycle (Rossi-Wilcox 2008). Alterations in subject matter were not the only changes that manifested in the Blaschkas' modeling. Equally important was their move to a photorealist style. To be sure, the connection between photography and realism was not automatic. The inability of early photography to capture color would have posed important challenges to identification and study. The shift may be interpreted as a byproduct of the type of objectivity that the Blaschkas were pursuing in the later parts of their careers, one aimed at creating models interpretable as specimens viewed through the photographic lens. As Daston and Galison note, photorealism has long been a sign of objectivity. Many different kinds of objectivities may exist at one time, but the cultural preoccupation with the photograph, at least among laypeople, has been enduring (2007).

In Daston's formulation, what constitutes the natural versus the human-made, changes in relation to shifting definitions of nature. Commentators on the Hellenic age discussed whether what to the contemporary eye is clearly a crafted cameo might in fact be a naturally formed object. Their confusion was possible because of different conceptions of the nature of the natural world (Daston 1998). Analogously, we might ask how ideas of the "lifelike" change over time in relation to the ways in which actors value life-likeness. It is easy to imagine viewers in some future time who might not perceive the Blaschka models as lifelike. In hindsight, with ample evidence for the models as examples of Art Nouveau and later photorealism, it is possible to say that if the models were "correct" scientific representations in their moment and their aesthetic qualities were ignored, then the Blaschka model style must have been either acceptable to the scientific community or entirely invisible to the Blaschkas' contemporaries. In either case, it seems that style is present in scientific representations.

The two styles that we can observe in the earlier and later periods of the Blaschkas' work met the demands of scientists at different times. The first is concordant in color and form with Art Nouveau. The later style, dominant in the botanical specimens, is celebrated as indistinguishable from a live specimen in photographs. No textual evidence has been found that would indicate that the Blaschkas intentionally altered their style. However, if visual analysis of the objects is accepted as evidence, something dramatic has happened in these differentiated aesthetics. To meet market demand, and probably as a result of copying the sketches of other naturalists, the Blaschka style changes radically.

The glass models in their time were not only objective but also aesthetic . This latter quality serves to guide interpretation, framing objects as something we can see *through* as a cultural lens. They can be interpreted not only as depictions of organisms as they were imagined in their time but also as the natural way of seeing the world at a certain point. Just as the design of technologies argues for a way in which the world works, these objects argue for the way in which the world looks. Style makes culture visible. Aesthetics was simply one resource that the Blaschkas enlisted to achieve their commercial goals, but the effects of their aesthetics on the consumers were potentially much greater. The models implicitly argue for the value of particular representational details: symmetry, fashionable colors, three-dimensionality, and verisimilitude (turgid rather than flaccid in preservation containers). The Blaschka aesthetic was political in that it signaled participation in the "correct" and "accurate" styles necessary to achieve certain ends. In Daston and Galison's terms, objectivity is found, in this example, to be subject not only to particular historical and cultural moments but also to specific aesthetic moments.

Both styles of model were praised by scientists in their moment for accuracy. They enact truth-to-nature, because both represent a type rather than an individual, but in different styles. Far from mere artistic flourishes, these styles reflect a change in scientific seeing. The later variant may look more "real" to us precisely because we are more used to seeing the world in a photorealistic way. Viewers of the anemone at the time of its use as a scientific model might have seen it as more realistic than viewers see it today. Perhaps the scientific eye is being shaped by style and the accepted model has more to do with that than has previously been recognized.

The impulse to do away with these subsequently subjective and dated representations, such as the Art Nouveau models, can only lead us to ask what style the later Blaschka works represent. Surely it would not be credible to believe that we have at last reached an objective style. Certain of the later Blaschka models can fool the camera and, therefore, the modern viewer, who has come to accept the cameras as productive of a particular type of realism, a style that is still embraced today. This aesthetic is invisible to contemporary viewers, so it can still be contended that the models look like the real thing precisely because Rudolf was able to move from Art Nouveau, which functioned to help make the early models acceptable as science, to a contemporary style that captures a new sense of the correct look for the scientific model.

CONCLUSION

The Blaschkas and the actors at Cornell configured meanings for their created objects according to their political goals: selling the models, positioning them in museums, raising funds for their preservation, and enrolling them in conservation projects. The Blaschkas took pains to fashion themselves as observers and naturalists, because their livelihoods were tied to the acceptance of their models as scientific. They carefully framed themselves as observers of the natural world and singular talents in glasswork to sell their wares. Their capacity to create accurate models for marine study can be seen as being necessary to selling models. Their models trained many scientists and influenced how marine animals were thought to appear. Cornell supporters of the models were happy to make claims that the models were important in science or art so long as the models were preserved.

In addition to revealing the categorization process, this study lays the groundwork for considering the relationship between aesthetic styles and scientific knowledge. Analyzing the ramifications that this may have for correct representation as bounded by science's taste at the time would reveal the importance of style in scientific work. The corollary to the claim of the indivisibility of artistic and scientific modes of thinking is that their modes of working may not be as different as generally assumed. Furthermore, both the categories themselves and the objects and people that they contain may be reconstituted into elements of the other network or reconstructed in novel ways.

A host of actors have drawn meaning from these objects. Just as the Blaschkas insinuated themselves in both art and natural history, self-fashioning their position through the term "natural history artisans," contemporary curators of their works position these artifacts in current networks of art and science. Scientist and curator Harvell emphasizes the potential of the models to draw attention to conservation, an application unlikely to have been foreseen by the artists. Art museum curator Wieslogel emphasized the Blaschka's work processes and technical ability, as well as the historical value of these objects. The efforts of conservators from the art and science sides to refigure the models in ways that justify their inclusion in their respective collections effectively remakes their value. As these knowledge communities undergo change, informing the unfolding processes of categorizing, labeling, and displaying the Blaschka models as *art* and *science*, a constantly recontextualized life is breathed into these artifacts.

3

MAKING SCIENCE VISIBLE: THE PHOTOGRAPHY OF BERENICE ABBOTT

"People say they have to express their emotions. I'm sick of that. Photography doesn't teach you how to express your emotions; it teaches you how to see."
Berenice Abbott, *Art News*, January 1981

"I wanted to combine science and photography in a sensible, unemotional way. Some people's ideas of scientific photography is just arty design, something pretty. That was not the idea. The idea was to interpret science sensibly, with good proportion, good balance and good lighting, so we could understand it."
Berenice Abbott, *Photographers on Photography: A Critical Anthology*, 1966

I encountered Berenice Abbott's photographs in person when I was preparing to teach a course on the intersection of art and science. I was standing in front of the archival cabinets in what was then known as the University of Virginia Art Museum, now the Fralin Museum of Art. New to the collections, I was eager to see what might be available in the way of work showing the relationship between art and science that I could connect to the interests of engineering students in my STS course. What struck me most immediately was how familiar the images were: the iron filings that concentrically spread out around the magnet points and the refraction of light through a prism were images I had seen before in textbooks. Perhaps not with the sharpness, clarity, and elegance of Abbott's images but certainly with similar intent and photographic design.[1] It seemed to

3.1 Installation view of *Making Science Visible: The Photography of Berenice Abbott* at the Fralin Museum of Art at the University of Virginia. 2012. *Source:* Photograph by Hiram Harmon Rogers.

me that these images might have had considerable influence on many other scientific images in very different formats and contexts, and I set about learning more about their maker's efforts in working with science. As it turned out, I would soon be embarking on a multiyear research and curatorial project with Worthy Martin, University of Virginia Associate Professor of Computer Science and Director of the Institute for Advanced Technology in the Humanities, *Making Science Visible: The Photography of Berenice Abbott*, to explore artistic and scientific dimensions of Abbott's photographs (figure 3.1).

Nicole Wade, then the museum's assistant registrar, had invited me to view a group of images from the permanent collection. She arranged four large-format photos across a large stand. Lit to capture the highest possible contrast, they depicted magnets with filings arranged over them, showing the capacity and effects of their magnetic fields. Demonstrative and illustrative of the concept of magnetism, the photos literalized the relationship between art and science. I would later learn that Abbott believed that photography was a bridge between art and science. She wrote that it was "the medium preeminently qualified to unite art with science. Photography was born in the years which ushered in the scientific age, an offspring of both science and art" (1959). Abbott's material and rhetorical moves positioned her work to access a reality that made her work fit into scientific programs. The long artistic career of this American photographer is distinguished by its range of subjects and diversity of collaborators from a variety of fields. In her younger years, she worked with some of the foremost artists of her era, including Man Ray in his Paris portrait studio in the early 1920s, and as a lead photographer for the federally funded documentary *Changing New York* (1935–1939). In the latter part of her career, she worked with cutting edge scientists, particularly physicists, at MIT through the early 1950s.

Abbott considered science to be a photographic subject as early as 1939, when she sought commercial image-making work with industry giants such as IBM and Standard Oil. Abbott would eventually become the photography editor of *Science Illustrated* in 1944, and she continued to work with the publication into the 1960s. In the post-Sputnik era, she would go on to create important images for the National Science Foundation's Physical Science Study Committee (PSSC) in a distinctive modernist style (1956). Her images of gravity, demonstrated by balls being dropped and shot using a stop-motion technique developed by electrical engineer Harold "Doc" Edgerton, a colleague at MIT, was the cover of *The Attractive Universe*, which she co-authored with Evan Valens in 1969. Versions of her gravity photographs continue to be familiar to science textbook readers. Abbott's efforts in scientific image making required revising her own self-construction as an artist. As part of her acceptance into a scientific network, Abbott made clear her intentions to increase public access to science through photography.

METHOD

My methods for this research followed curatorial practices, which place me in a position of participant-observer: as much as I considered the way in which Abbott positioned herself in terms of the field of science and art, in some small ways I also contributed to the way in which she was situated through the production of the *Making Science Visible* exhibition. I used curatorial methods that are frequently employed in museums on both the art and science side that are a hybrid of historical analysis, biographical and period research, and image interpretation (von Bismarck 2021; von Bismarck and Meyer-Krahmer 2020; George 2015). The central item that stands out most is how often ideas of what STS scholars would recognize as interpretive flexibility are at the fore. The concept of interpretive flexibility (Pinch and Bjiker, 1984), or the tendency of users to interpret and use technology in ways other than its creators intended, would be recognized by curators. The shared word root *techne* in art and technology would be one place to start in teasing out these connections. Another point of departure would the use Pinch and Bjiker make of the concept of "artefact," though surely the most salient point is simply that the practice and results of the analysis are to the same end: to understand how others have understood the same object.[2]

Curators would hardly recognize the terminology of STS methods (and vice versa), but they would surely recognize the practices themselves. Many curatorial methods function as critical inquiry by bringing a history of interpretive flexibility when different curators and institutions have understood objects differently and have made efforts to reiterate them in new contexts to produce or highlight specific possible meanings. The curator does her best to review these uses and in doing so develops an account of the moments of interpretive flexibility around the object before engaging in this practice herself. My research on Abbott began with a review of the textbooks to which she contributed, then moved on to a survey of her science images. Eventually, this led me to research Abbott's life in preparation to curate an exhibition (*Making Science Visible: The Photography of Berenice Abbott*) of her work for the University of Virginia's Fralin Museum of Art. I employed a number of curatorial methods in this portion of the research, including considering her photographs in the various science, documentary, and art contexts in which they appeared; the uses to which curators had placed her photographs; and the arguments made by placing her images alongside the work of other photographers. Most often, this had been done in the context of historical retrospectives on the Federal Art Project (1935–1939), part of the Works Progress Administration, or more generally in the context of

Depression-era artists. These methods are informed not only by exhibition publications and museum exhibition records but also by the visual materials themselves. because the goal of such research is, in the end, to mount the images in a way that allows viewers to see them anew and to take away a more nuanced understanding of Abbott's work. This places the curator in a position akin to that of the artist or scientist: to use materials, albeit aided by textual rhetoric, to make an argument.

Through the development of the exhibition, I spoke to scholars who had written about Abbott and to education scholars about Abbott's contributions to pedagogical images. The exhibition *Berenice Abbott: Photography and Science: An Essential Unity* appeared at the MIT Museum in the same year, and I benefited from conversations with Ron Kurtz and from his excellent catalog *Berenice Abbott: Documenting Science* (2012).

Curators are knowledge makers. The overlap that some curatorial methods have with STS practices, particularly by way of the attention to what STS scholars call *interpretive flexibility* and what curators see as a basic idea fundamental to their practice, should encourage ASTS scholars to consider the ways in which these practices may be particularly fruitful in engaging with materials at the intersection of art and science.

LEARNING TO SEE

At the time I saw Abbott's photographs at the University of Virginia, I was familiar only with Abbott's influence on documentary practice and her work with cityscapes and rural laborers. I had grown accustomed to asking my students to look carefully at eighteenth-century drawings of animals discovered during Europe's colonial expeditions to understanding secondary observation and the role of texts as guides for rendering images. I asked them to consider the pedagogical value and celebration of science and mathematics contained in German Renaissance printmaker Albrecht Dürer's *Melencolia I* (1514) to understand how this homage to Enlightenment values functions through its combination of mathematical and religious symbols.

In contrast, Abbott's work intuitively seems more familiar to the viewer. That is not surprising, because her images were widely used by scientists to teach science. Whether we consciously remember it or not, many of us have encountered this style in one form or another. Yet active aesthetic choices of the image maker can be more easily hidden by our contemporary assessment of the "correctness" of the image. Our belief in the particular scientific principles and details contained in the image can give the depiction an aura of objectivity, obscuring the work that artists put into creating the images.

This apparent simplicity belied the stagecraft necessary to produce such a realism. Abbott's success in these images was that they captured the subject so completely that they hid her own artistic labor. Having used the rather obvious "errors" of colonial painters as a shortcut to showing students how aesthetics and historical science functioned as intertwined knowledge, Abbott's science images offered a new set of interpretive problems. Abbott aligned her material practice of photography with a rhetorical practice of defending realism as the proper use of the camera. Reconciling historical understanding of science with historical understanding of representation provides an entryway to understanding how science was constructed in this context. In my role as an educator, then, I sought to position Abbott's work as contributive to science, claiming a special role for her photographic practice in that process in the context of the power dynamics between art and science. The question was how to teach my students to "see" these dynamics. Promising more Abbott images on my next visit, Wade smoothed the edges of the archival tissue over the images, and they disappeared into the cabinet of photographs.

Learning how and what to see is a central skill in science. In this sense, practice trains the eye. What we see is, in fact, a perspective, and therefore changeable. The skill of seeing and knowing how to look are fundamental to creating expertise in science. As Abbott expressed earlier, the right use of tools is required for proper seeing (Lynch 1988). Like the Blaschkas, Abbott used what she called a realist style, one commensurate with the needs of scientists. Unlike the glassmaking team, however, Abbott employed realism in the service of popularizing science for the public good. Her goal of offering accessible images of the science of everyday life, distinct from the agendas of the scientists for whom she worked, aligns her with the tactical media practitioners of the 1990s and 2000s that we will encounter in Chapter 4.

Abbott's ideas about what photography could do to educate the public by casting social issues in a new light are well documented in studies of her photographs. How this impulse was extended and took shape in her science photographs has received less scholarly attention, giving rise to a sense that Abbott has created separate bodies of images. Although these early and late images do show some distinctions, treating them as entirely separate spheres obscures Abbott's interests in both projects. This in turn has informed interpretations of her science work solely in terms of photography in the service of science.

A more holistic consideration of Abbott's work would address her realist aesthetic and philosophy of what camera technology could offer her viewers, a group she conceived of as a polity in need of a science interpreter. In contrast to tactical media, Abbott embraced technology as an instrument that could service science, a relationship she believed enabled the camera to realize its maximum potential. Her science images offer art historians a chance to see the body of Abbott's work afresh and to consider the contributions of artists to scientific knowledge communities.

The images also lend insight to the effects of rationalist thinking on artistic practice. Abbott was often at odds with artists whose pictorial approach she defined as being in opposition to her own work. To her, human vision was flawed; only the camera could lay bare the facts. As she put it, "What the human eye observes causally and incuriously, the eye of the camera notes with relentless fidelity." This belief is familiar to readers of Daston and Galison (2007): The photograph, which was the essence and emblem of mechanical objectivity, carried no metaphysical cachet; at best it was an accurate rendering of sensory appearances, which are notoriously bad guides to the "really real." It also would not have passed muster with aperspectival objectivity, which eradicates all that is personal, idiosyncratic, and perspectival. The photographic "look" was in fact radically perspectival—as many of our X-ray users never ceased to lament. We can fully understand why photographs wear the halo of objectivity only when we recognize that the kind of objectivity that beatifies them is mechanical objectivity, and not its metaphysical or aperspectival kin.

None of this should detract from Abbott's contributions to science. Even as she upheld the camera as having ostensibly objective properties, she problematized this position by suggesting that it was possible to use the instrument in ways that were *not* true to its nature. To be sure, Abbott regarded such applications as error. She opposed the use of the camera to mimic older forms of artwork, arguing instead for a type of photography that avoided the conventions of painting, a position that would alienate her from the American photographic establishment. The camera could surpass those forms only if it was not misdirected, particularly through technical interventions in film development. To merit serious consideration, Abbott insisted, photography "must be directly connected with the world we live in."

Yet achieving fidelity took craft. Unlike art photography of the time, Abbott's brand of photorealism required elaborate staging to avoid having to tamper with the image in the development stage. Her earlier schooling in the artistry of photography would prove a crucial element in her ability to use the camera to capture scientific truths.

EARLY YEARS

Abbott was born in Ohio in 1898 and was the youngest of four children born to Lillian Alice Bunn. After two semesters at Ohio State University, she initially planned a move to New York to study journalism at Columbia University. In 1918, she moved to Greenwich Village, where she met artists, poets, and political activists. She trained independently in New York as a sculptor, published experimental poetry, and met avant-garde leaders Marcel Duchamp and, most important, Man Ray, who would soon move to Paris. In 1921, Abbott left New York for Europe, traveling first to Paris and Berlin before settling in Paris. In France, she became Man Ray's photographic assistant when he arrived about a year after her transatlantic move. The move would eventually lead Abbott to shift from image processing to image making. She had her first solo show at the gallery Le Sacre du Printemps in Paris in 1926, which included a number of portraits such as her classic image *James Joyce, Paris*. There, she met Eugène Atget about two years before his death. Hearing that he had passed away, she sought out his photographs and worked to raise his profile. Atget had been an artist's photographer who created images, mostly of Paris, for study by artists who often made use of his viewpoints. She worked to create interest in Atget's contributions to the art world and was credited with solidifying Atget's legacy by reproducing his work from negatives. In 1929, Abbott returned to New York, where she was impressed with the building scape that had developed in the postwar boom years. She made important photographs of the city just before the start of the Great Depression. As this economic event set in, she found employment directing the social documentary *Changing New York* for the Federal Art Project, receiving a salary and assistance (Massachusetts Institute of Technology 2012).

Abbott focused her camera on the built space of the city itself. Some of the most celebrated images are of iconic buildings and skyscrapers, evincing an interest in the advanced technology of the time. In a documentary on her work and life (*Berenice Abbott: A View of the Twentieth Century*, 1993), Abbott explained her interest in urban environments as flowing from her belief that "the city expresses people better than people express people." In this sense, the project continued her work in portraiture, only this time the portrait would not be of an esteemed artist but of society as expressed in its monumental works of infrastructure. Elizabeth McCausland (1899–1965), the art historian and social critic and Abbott's lifelong partner, wrote the text for the project, and her critiques of art coincided with Abbott's ideas about new aesthetic development turning away from representing reality (University of Chicago 1966; McCausland 1973). In a 1938 pitch to her editor, Abbott wrote, "I want my book [. . .] to reach a new audience, not the audience of scholars, connoisseurs or museum directors, but the audience of simple American millions, without whose support and intelligent understanding America cannot hope to produce a vital and democratic art."

Abbott had a critical view of abstract painting despite a close friendship with Arthur Dove, often considered America's first abstract painter. This shared philosophy of art in the public interest bound Abbott and McCausland to social realism, ideas they further developed over the course of *Changing New York*. Together, they completed this ambitious venture in 1939. In all, Abbott worked on her vision for six years before being hired by the Federal Art Project. She completed the project four years later, having worked for a decade to produce the documentary (Abbott et al., 2012;

Ware 2004, 2–3; Sullivan 2006, 122; Weaver 2013). In 1944, Abbott was one of the first members of the American Society of Media Photographers (ASMP), a union primarily of visual communicators and commercial photographers. In a 1990 interview with the organization, she described her motives for joining as stemming from her treatment when she worked for IBM photographing computers: "I joined ASMP because I believed in unions for people, and photographers were having a terrible time. IBM, for instance. They wanted some work done on their computers, and an ordinary photographer couldn't have done it. So they hired me. But they wouldn't give any extra money. We really got the dirty end of it." One of Abbott's photographs shows a woman working on an IBM calculating machine.

As early as April 1939, Abbott was articulating her reasons for focusing on science images. By 1944, she had become the photographic editor of the general audience science magazine *Science Illustrated*, a publication that survived only until 1945, when McGraw-Hill purchased it. Abbott scholar Terri Weissman has argued that this was a stroke of luck, a turning point in Abbott's shift toward science imagery (2011). At *Science Illustrated*, Abbott ran photographs that the contemporary eye might well have found feminist in their insistence on representing women and domesticity in explaining scientific phenomena. For example, Abbott's image of static electricity centers on a woman with a hairbrush, which connects the everyday activity of grooming with the science of electricity through the concept of static transfer to the hair.

However much of Abbott's photography was influenced by her new science subjects, many of the skills crucial to the creation of the pictures that would appear in *Physics* had been honed in previous pursuits. In his introduction to *Berenice Abbott: American Photographer*, art historian and critic John Canaday likened Abbott's preparations for her ideal picture to capturing a scientific specimen. For Canaday, it was "almost as if a trap had been set" (O'Neal 1982). For her famed photograph *New York at Night*, she explained:

> I took this early in the evening. There was only one time of the year to take it, shortly before Christmas. I started about 4:30 PM and didn't have much time. But I had done a good deal of prior planning on the photograph, going so far as to devise a special soft developer for the negative. This was a fifteen-minute

> exposure and I'm surprised the negative is as sharp as it is because these buildings do sway a bit. I knew I had no opportunity to make multiple exposures because the lights would start to go out shortly after 5:00 PM when the people began to go home and so it had to be correct on the first try.

At sunset on December 20, 1934, Abbott's preparation paid off when she captured this iconic image of New York. Abbott was quick to reference her artistic roots even when creating explicitly scientific images. In describing the inspiration and technique for creating her wave pattern series on light-sensitive paper, she credited the Bauhaus professor and Hungarian painter/photographer Moholy-Nagy and her employer, Man Ray, both of whom made priority claims on the 1922 invention of the photogram, creating an image using light-sensitive paper but without the aid of a camera. "My idea," she explained, "was to do a rayogram in motion. Moholy-Nagy and Man Ray had done pictures by putting objects on sensitized paper but I wanted to do the same thing in motion."[3]

For Abbott, this kind of image making, like photography itself, had roots in both art and science practice. These intertwined strands made photography well suited to her purposes. It was the proper way, she felt, of bringing the public into scientific conversations. In her manifesto on photography and science, she wrote that "we live in a world made by science . . . There needs to be a friendly interpreter between science and the layman. I believe photography can be this spokesman, as no other form of expression can be."

Abbott's goals for her scientific projects aligned aesthetically and intellectually with her previous documentary projects in that they called for the employment of realism, with the aim of helping the public understand the world. Abbott's realism was further defined by the consciousness of her social documentaries and her discursive and pedagogical science rooted in her approach to photography. As outlined in two influential essays, "Straight Photography" and "Documentary Photography" (Abbott 1941), this philosophy derived from her subjects. Unlike her social documentary, however, Abbot's science images were meant not to inculcate critical reflection on science as a social process but rather to assist in the interpretation of reductive science. If we understand Abbott's work as representative, this would align her with a large swath of work that is today sometimes referred to as "sci-art."

BIG SCIENCE, BIG ART

As a photographer and editor for *Science Illustrated*, Abbott frequently engaged with scientists. It was not until 1958, however, that Abbott would be paid to create science images. The catalyst was the Sputnik crisis, and once again Abbott found employment with the government. She was hired by the PSSC, set up in 1956 by MIT scientists to investigate and revise the physics curricula across the United States, particularly at the high school level. Supported by the fledgling National Science Foundation, the PSSC had among its charges the development of teaching aids, especially film and visual materials, and among its major projects was a textbook. Entitled *Physics*, the text was designed to encourage excitement and interest in the subject rather than emphasizing memorization (Abbott et al., 2012).

Abbott's role was to create photographs for *Physics*. Her photographic experiments at PSSC would yield iconic images that influenced both informal and formal science education. Her style of preparing the conditions for photography, rather than creating alterations in the darkroom, required assemblage of precision apparatus and exacting techniques. As such, her work was not dissimilar from that of the scientists who populated nearby laboratory spaces at MIT. Abbott invented what she needed as she worked, developing cameras and equipment such as specialized tripods as well as techniques suitable to individual subjects. Her standards and requirements for complex materials, which sometimes involved an individual build for a single shot, might be thought of as a kind of "big art," a parallel to the "big science" with which she was colocated.

With the advent of the space race, and science now a matter of national security, science communication was suddenly important. In the wake of the shock resulting from the Sputnik launch, Abbott thought, "now people might think a little differently." The hope that a change in public attitudes and financing might make possible her photographic studies of science spoke to her belief that current events were both the impetus for and the raison d'être of her efforts. It also related to Abbott's livelihood as a working photographer, however. As the child of a divorced mother, Abbott had limited means, so her production of large-scale artistic projects is all the more remarkable. She was a working artist throughout her life. She taught art and photography, published books on photography, began a commercial gallery, and patented a number of photographic tools. Like many artists, Abbott was also an inventor and held a number of patents for photography-related designs. She attempted to develop and market these innovations through a short-lived corporation she founded in 1947 called The House of Photography. Tools she developed including the lighting pole, now known as the *autopole*; a 20-pocket coat designed to hold everything that the photographer on the move could need; and the Abbott Distorter, which she used to create a self-portrait that shows a recognizable Abbott with oversized eyes looking directly into the camera.

Even before founding the company, Abbott devised a new type of camera called the super-sight (O'Neal 1982).[4] The supersight camera was particularly helpful in capturing the enlarged details often needed for her scientific images. This unwieldy camera was the opposite of a camera obscura: objects were placed inside it to be photographed (Sullivan 2006). In a camera obscura, the world passes through a tiny slit and is projected (to be traced either on paper or onto film). Abbott's supersight camera works in precisely the opposite way: a small field comes through the camera and is projected as a very large image directly onto film, producing a detailed, grain-free image.

Critics might view Abbott's interest in science as a means to produce a steady stream of income to allow her the freedom to work on projects more closely associated with art. This, however, requires us to ignore both the many years that it took Abbott to find positions in science and the way that she describes her science work as a public service. During this period, her artistic training was brought to bear in a number of ways, and, in a telling commentary of her commitment, Abbott did not take on any other large-scale projects. During her time at MIT, Abbott produced a number of photographs and photographic techniques for displaying concepts such as gravity, light, and magnetic fields, which are not usually included in discussions of her artistic contributions despite their continuing influence on how these ideas are imagined and on pedagogical scientific illustrations.

Though credited as an individual on many of her science photographs, Abbott is not remembered primarily as a science photographer in art history. Her photographs have also not elevated her to any considerable status in the science community. Abbott's status in relationship to her photographs and her relative standing in art and science may be amplified by the norms of art and science or through an interaction effect, in which she understood the practices of each group and positioned herself accordingly. So complete is the anonymizing of her work in science that she is not identified with the stop-motion images of balls that she created to depict gravity. This is perhaps more a reflection of the status of image makers in science than the identification of the photographer in art. This separation is possibly evidence of Abbott's ability to position herself. So convincingly did she situate herself first as a portrait photographer, then as a documentarian, and finally as a science imagemaker that scholars of her work have tended to separate those bodies of photographs into separate careers (Weissman 2011).

Creating ways of seeing art and science work across a single individual's career surely enhances our knowledge of the person and their respective pursuits. Among those images assigned to the science part of her career is Abbott's often duplicated and reproduced photograph of a bouncing ball that was used to depict gravity, which appeared on the cover of *Physics*. It was produced using flashing lights during her work with Harold Edgerton (Massachusetts Institute of Technology 2012). Edgerton was an electrical engineer at MIT who was working with strobe lights and photography to capture stills of fast motion in physics. He maintained a lifelong association with photographer Gjon Mili of *Life* magazine, a venue where Edgerton published many of his photographs. In 1957, Edgerton created the *Milk Drop Coronet*, which uses his revolutionary stop-motion photography techniques. Though they are sometimes described as having very different backgrounds (Abbott from the art-side and Edgerton from the science-side), Abbott and Edgeton both worked with techniques related to an object's motion through photograph with a focus on capture the moment in front of the camera lens by manipulating light, rather than suggesting motion through darkroom techniques. Both photographers became well-known for their contributions to the physical sciences understanding of objects positions in cases where the movement was beyond the comprehension of the human eye alone. Abbott's falling wrenches in her photograph *An Asymmetrical Object Behaves Symmetrically* (1958–1961), that illustrated a scientific principle. The wrenches demonstrate the law of averages, with a single center point in the wrench staying in the same place as the object falls.

One of the most interesting aspects of Abbott's work in this period was her recognition of the collaborative nature of science practice. The gravity photos, for example, had required large teams and careful coordination of the dropping object, camera, and lighting. Abbott remained committed to showing what was in front of the lens and avoiding darkroom corrections to the extent possible. In this way, she seemed relatively less interested in the staged "subjective" world behind the lens. Nevertheless, the convivial nature of collaborative big photography agreed with Abbott, and she referred to this period as "the happiest years of my life" (Abbott and Mitchell 1979). This time ended, she recounts in *Berenice Abbott: A View of the Twentieth Century* (1993), when her job was given to a younger man whom she had trained. Abbott remarked, "the world doesn't like independent women, why, I don't know, but I don't care." She would soon relocate to Monson, Maine, where she would work on her labor and place photographs.

SCIENCE OF THE EVERYDAY

Among the contexts that Abbott's images spoke to was the science of everyday experience. A good example is *Soap Bubbles* (1945), reproduced in *Science Illustrated* in July 1946 to illustrate an article explaining the chemistry and mechanics of soap. It discusses washing and featured a companion piece on synthetic fabrics, suggesting that the publication hoped to reach beyond the boys and young men typically targeted by the popular science media. In *Soap Bubbles*, Abbot illustrated the geometry of soap froth, explained in the accompanying text as the consequence of molecular differences between hard and soft water.[5] Using her supersight camera (Abbott et al., 2012), Abbott had to conduct repeated experiments with types of soap to capture this image, one of her most frequently reproduced and copied. Through such quotidian science communication, Abbott hoped that the public would be increasingly interested in supporting scientific inquiry.[6]

Abbott also worked with prosaic biological subjects, though even in these relatively simpler images she sought to suggest the relationships between subjects. For the science textbook *American High School Biology*, Abbott photographed a Japanese beetle (*Popillia japonica*). The insect had turned a leaf into a latticework of veins. This text (Grant, Cady, and Neal, 1948) took the unusual step of visibly crediting Abbott with each photograph as "Miss Berenice Abbott." It introduced early ideas about ecology for classroom readers. Individual organisms are pictured with other organisms, and their relationships are the focus of the text. Of particular interest are agricultural "pests" pictured with the plants that they consume. Rather than showing insects in isolation, Abbott encouraged viewers to think of the effects of the Japanese beetle in an ecological context. In this staged image, the background is the leftovers of a leaf meal, complementing the text's points about the relationship between these two organisms.

The contrast in this image's relational aspects is made starker when compared to Abbott's large-format *Untitled* image of the giant water bug *Lethocerus*. The specimen is on its back with no special background so viewers are encouraged to note the sections of the body and the articulation of the insect's legs. Images in science textbooks need to be constructed both to fit into current scientific culture and to demonstrate specific features that scientists are trying to convey. The problem for the photographer, then, is how to encourage the viewer to notice those aspects of the image that match scientific purposes. In this photo, Abbott has removed all context through careful lighting, which minimizes the visibility of any shadows cast by the subject. The framing and orientation give the strong impression that the insect is large. Abbott's exaggerated framing lacks the pedagogical aims and context of the textbook image, the contrast serving to underscore the artist's contribution to new ways of creating images to understand biology.

In explaining her motivations, Abbott put herself in the position of the viewer requiring scientific interpretation: "The idea was to interpret science sensibly, with good proportion, good balance, and good lighting, so we could understand it." Taken in conjunction with her claims for the camera's "relentless fidelity," her explanation of the ideal popular science photograph demonstrates the tension between the role of the artist in making choices and what Abbott believed was the objective use of camera technology. For Abbott, the trick was to render her craft invisible to viewers to create a photo that appeared to expose the facts of science while preserving its aesthetics: "The scientific photographs had to be carefully composed, but they couldn't look that way. I didn't want the composition to be so obvious as to take over . . . when you look at a photograph and all you can see is the composition then you know it is a big flop" (O'Neal 1982).

Many photographers and other scientific image makers are heirs of the ideas for science photography and even the image style that Abbott proposed. One example is Abbott's concept of a photo that acts as an illustration. Prisms are familiar subjects for optics photographs, but in Abbott's *Light Through Prism*, viewers encounter a different kind of prism made to show refraction and reflection. In this photo, viewers see Abbott's setup from the top. She describes arranging two glass triangles with water between them, being sure to avoid creating air bubbles, and held together by cohesive force. The separate beams of light enter the prism at a variety of angles. In the first three beams, viewers can actually see refraction displacing the light slightly, the way a bent straw in water would look. By the time we reach the latter three beams, however, the angle of their entry causes the beams to reflect off the right triangle wall, crossing through the upper part of the triangle. The beams are reinforced as they cross, so spots of brighter light are produced. Abbott explained that creating this effect took thoughtful staging: "Multiple beams of light from a source change direction when they go into a glass plate and when they emerge. Some waves are reflected inside the glass and then escape. The prism photograph was done very carefully. The prism was filled with water and not one drop of air was inside. The box that held the light source was specially designed and purposely looks as it does to make for a better composition" (O'Neal 1982).

This careful composition was necessary to the two natures of lights that Abbott was attempting to illustrate. She reminds us of the particle and wave nature of light beams by producing an image that shows the beams of light as being smooth when inside the prism but discrete when outside it (Weissman, 2011). Weissman proposed the term *photodiagrams* to describe these illustrations through photographs, which do not show the phenomenon itself but rather purport to offer a way to understand it. For Abbott, these images are not simply attractive designs abstracted from phenomena but proof and demonstration of science ideas through photography.

SCIENCE, DEMOCRACY, AND THE REALIST IMPERATIVE

Artists and image makers are typically considered to be outside science, even when their contributions enable instrument design and data visualization as well as science communication and critique (Weissman, 2011; Kurtz 2012). Abbott's experience is a corrective to this view. By the early 1960s, the PSSC had enlisted nearly 20 percent of US high school physics teachers into its efforts and was a major force in reshaping physics curricula worldwide (Daeschner 1965). Abbott's images for this project do more than document a historical moment in science. They materially contribute to pedagogical practice and, in particular, the expansion of visual practices at a particular moment in science history. They do not just illustrate or draw attention to science. The visual language of these photographs helps us experience and observe scientific processes, from the consequences of the laws of physics to contrasting visions of the biological world.

Abbott's realist impulse aligns with her goals for democratizing science. We can readily see how her rhetoric supports the idea that her photographs would represent a reality in which viewers could observe the workings of scientific phenomena. Abbot understood that her realist aspirations for photography contrasted with the efforts of her peers such as Alfred Stieglitz, whose work she described as "art . . . by the few for the few." In *A Guide to Better Photography* (1941), Abbott critiqued the pictorialists. She believed that what was in front of the camera was of secondary importance for these artists, who selected subjects primarily to showcase and experiment with photographic processes.

Abbott also took issue with what she saw as a display of darkroom techniques over subject matter. For her, "photography is for communicating the realities of life." In an address for the Aspen Institute Conference on Photography in 1951, Abbott stated the following:

> . . . this medium of photography is so young that it is not fully understood by experts or by photographers. The greatest influence obscuring the field has been pictorialism. At this point it may be appropriate to define pictorialism.

> My definition would be something like this: that pictorialism means chiefly the making of pleasant pretty pictures in the spirit of certain minor painters. What is more, the imitators of painting imitate the superficial qualities of painting, are not themselves aware of the true values for which painting strives. The only relationship is that of a two-dimensional image on a flat surface within a certain area, but the natures of those two images are worlds apart. Photography can never grow up and stand on its own two feet if it imitates primarily some other medium. It has to walk alone. It has to be itself.

Abbott may have sought the truth available only through photography. The material of her photographs aligns with the aims of her rhetoric. A clear vision of what was in front of the camera was necessary to her sense of the realist purpose of photography as well as to her sense that the public needed photography as a bridge into "the world made by science." She believed that though the camera might be directed to produce images in a style evocative of earlier artistic media such as painting, the proper use of the camera was to avoid duplicating old styles. For Abbott, the best use of the camera was to render detail faithfully and thereby to reflect what she saw as realism. Her photographs and her descriptions of them defend an objective reality at odds with many of her photographic peers and in conflict with Daston and Galison's critique of the camera as an attempt at mechanical objectivity (2007).

However simplistic Abbott's motives may now appear to us, the influence of her photographs on how science was imagined by readers of *Science Illustrated* and *Physics* should not be underestimated. In her images, Abbott and many of her viewers saw what they believed to be an objective reality, devoid of postexposure tampering and visualizing what hitherto had been unseen. Abbott's wish to show only what was before the camera, coupled with her desire to educate the public about science, produced ironic dual images: photodiagrams that were at once illustrations of unseen scientific phenomena and photographs with a weight beyond illustrative representations taken to be less than objective.

Abbott's penchant for highly staged works also emphasizes her interest in what was in *front* of the camera, rather than darkroom processing techniques. In the case of scientific images, this meant making the ideas of science broadly available. Abbott attempted to communicate, and thereby democratize, what she saw as the power of her time—science—and to encourage engagement with science. To accomplish this, Abbott's images speak to knowledge communities in both art and science. Through her documentary photographs, Abbott is recognized as having contributed in an important way to social purpose through the arts. Abbott's science photographs should be seen in a similar light. For her, these images represented a way for the camera to reach beyond previous artistic media such as pictorial photographs and beyond typical aesthetic subjects into another arena of social progress. Her science legacy includes new ways of understanding what a photograph could add to scientific literacy and developing one potential role for the photographer in science practice.

EXCAVATING ART-SCIENCE

The story of Abbott's work in science can help STS scholars cast into relief the contributions of artists who have seen themselves, or have been seen by others, as serving science. The art community frequently derides such work as lacking ideas or privileging communication content. For its part, the science community celebrates the "useful" qualities of such work but does not recognize it as a contribution to the project of science. Despite being fundamental to the practice of science and crucial to knowledge transfer between scientists, their students, and the broader public, images made for use in science are too frequently pictured as not contributing to the project of scientific knowledge making (Latour 1986; Lynch 1988). On one hand, these artists are seen as the instruments of scientists because the scientist disciplines the artist's work. On the other hand, such artists are seen as not contributing to the world of art because their work is delegated to auxiliary status, craft, or even advertisement. Scientists' limited knowledge of artisanal craft, however, suggests that artists are adding something more than technical work to the scientific process. Such workers range from artists who work as technicians, including sketch artists and photographers who served on exploratory missions (Codling 1997) and inside science labs, to those who, like the Blaschkas, worked for scientific institutions but did not directly collaborate with scientists on a daily basis.

Abbott coupled a role as a science image maker with a distinct philosophy of science in the public interest. This alignment between the interests of artists of this type and scientists tends to mask the artist's agency in producing science work. In later chapters, we will observe artists whose work is at odds with parts of the science community. Like STS scholars who follow failures to understand the practices of science, these mismatches in goals and even direct critiques of science illuminate artists' contributions to the scientific knowledge making and controversies. This does not mean, however, that these contributions are not present in cases where there is philosophical alignment. Though the differences may be subtle, many of the same processes are at work.

Understanding the contributions of artists, even those who did not claim to contribute to science, is just as important to exploring the intersection of art and science as examining the work of artists who critique and contextualize science. Indeed, the role of the STS scholar is to observe what is happening in the social world of science, regardless of what scientists (or artists) say is happening. For the analyst, following the rhetorical moves of actors in concert with their practices is necessary. The STS call to follow the actors may ring especially true in the case of art, because artists who work in science often have an economic stake in not insisting to scientists that they are full participants in the enterprise. In some cases, artists themselves may not always understand their contributions to science. More often, it is likely that economic factors are in play, because scientists have greater access to government and corporate funding, so they are in the position of hiring artists as employees or contractors.

It is not surprising, then, that artists like Abbott rhetorically positioned themselves, perhaps somewhat defensively, as essential to the scientific enterprise. In the documentary film *Berenice Abbott: A View of the Twentieth Century*, Abbott recollected that in her 1958 interview at MIT with Dr. Elbert Little, she argued "that scientists were the worst photographers in the world," but that "they need the best—and I was the one" (Weaver and Wheelock, 1992). Although it may be clear to STS scholars how vital visual representation is central to the practice of science, that point may be less obvious to a scientist or artist.

Scientists have tended to see image and model making as auxiliary to their aims, though Latour (1986) and Lynch and Woolgar (1990) have shown that image making in particular is fundamental to the scientific process. Elsewhere Lynch (1988) has shown the relationship between analytical visual displays and quantification vis-à-vis images. Other

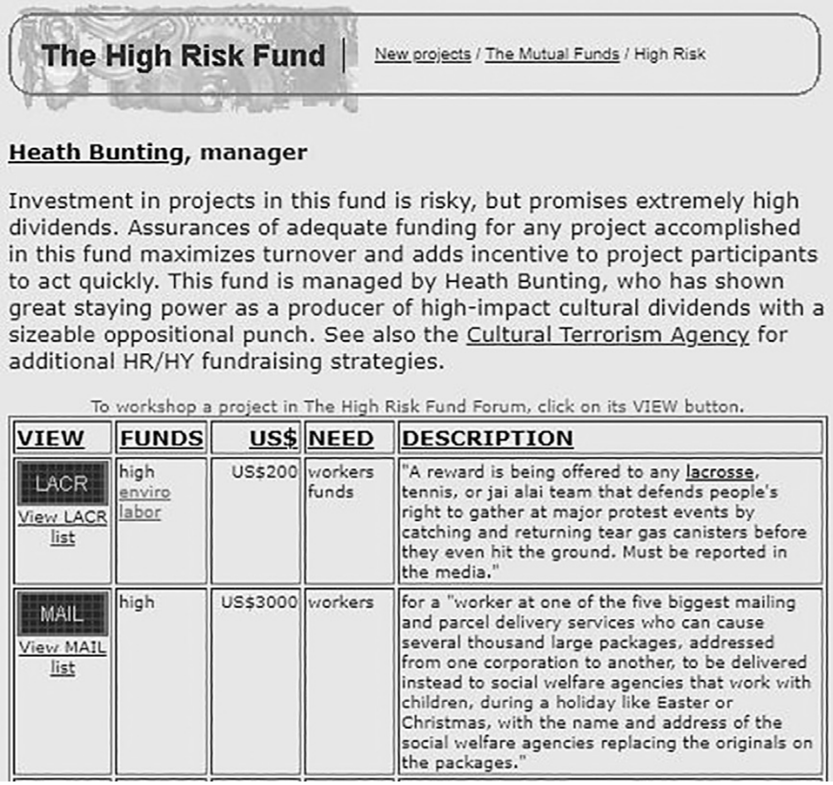
STS scholars, including Elgin (2010), Castel and Sismondo (2002), and Downes (1992), and philosophers of science (Black 1962) have made the case that models, too, are fundamental to scientific understandings. Models and images are more than objects of demonstration or ways to derive theoretical perspectives: to paraphrase Nancy Cartwight, they themselves are a theoretical perspective (1983). With this in mind, close studies of artists' contributions to science appear even more necessary.

Like technicians and others considered outside the scientific enterprise, science-engaged artists are, in fact, understudied science workers. Some efforts have been made to comprehend what scientific images encode beyond their role in the scientific process. Kathryn de Ridder-Vignone (2012) has shown that well known artistic conventions are often enlisted in situating scientific images as part of a perceived artistic discourse. In the case of nanoimages, de Ridder-Vignone's example, received artistic styles like landscapes were harnessed in situating these images as art while also keeping account of their scientific value. Until we come to terms with the multiplicity of skills and persons involved in science, however, including its artistic aspects, our understanding of the social shaping of science will be incomplete. As we have seen in the case of the Blaschkas, aesthetic values are encoded as well, in ways that STS scholars have hitherto found difficult to decipher. Combining STS tools with those of art historians and visual culture scholars may start the process of developing a key.

4

THE PRACTICES OF TACTICAL MEDIA

At the turn of the twenty-first century, the popular and scholarly possibilities of the internet as a space of both utopian expression and commerce were beginning to be realized. In the primeval, inchoate World Wide Web emerged groups of activist practitioners of forms of art involving technical computing skills and interested in the affordances of the internet as a medium for social intervention. If you had been surfing the web in the early 1990s, you might have happened upon *®™ark.com*, with its slick front page belying its sticky text. This seemingly corporate website declared that it offered "complex solutions for a simple world™" (2000a). A few clicks later, readers could find a list of more than a dozen "mutual funds" looking for sponsors to help carry out tasks by providing workers, money, or offers to complete projects for a given investment (figure 4.1). Some readers might have been drawn to the page of "The Environmental Fund," described as "a good start for the first-time investor." The page framed these projects as possessing minimum risk but "high potential yields and universal appeal." The fund listed this under the abbreviation CEXP, with "workers and funds needed" to "call attention to the planned obsolescence of various computer products, place 'best before' dates on various components, either by silk-screening or with stickers placed on retail boxes." ®™ark was designed to suggest the existence of an elaborate network of conspiring artist–activists. In fact, the participating artists and



The High Risk Fund

New projects / The Mutual Funds / High Risk

Heath Bunting, manager

Investment in projects in this fund is risky, but promises extremely high dividends. Assurances of adequate funding for any project accomplished in this fund maximizes turnover and adds incentive to project participants to act quickly. This fund is managed by Heath Bunting, who has shown great staying power as a producer of high-impact cultural dividends with a sizeable oppositional punch. See also the Cultural Terrorism Agency for additional HR/HY fundraising strategies.

To workshop a project in The High Risk Fund Forum, click on its VIEW button.

VIEW	FUNDS	US$	NEED	DESCRIPTION
LACR View LACR list	high enviro labor	US$200	workers funds	"A reward is being offered to any lacrosse, tennis, or jai alai team that defends people's right to gather at major protest events by catching and returning tear gas canisters before they even hit the ground. Must be reported in the media."
MAIL View MAIL list	high	US$3000	workers	for a "worker at one of the five biggest mailing and parcel delivery services who can cause several thousand large packages, addressed from one corporation to another, to be delivered instead to social welfare agencies that work with children, during a holiday like Easter or Christmas, with the name and address of the social welfare agencies replacing the originals on the packages."

4.1 *"The High Risk Fund." Source:* ®™ark's mutual fund listings. 2000. http://archive.rhizome.org/artbase/1693/fundhigh.html.

thinkers played a variety of roles, including fund manager, allowing their names to be used on the website. In addition, the web pages encouraged readers to contribute their own investment ideas (R™ARK 2000b).

This set of practices came to be known as *tactical media*, a mixed-method art form that developed around the early internet and took advantage of the network's user-enabling open-endedness, manifesting in a range of provocative actions, typically with a view to social commentary. ®™ark's website used a corporate business–style veneer to draw the reader into a complex set of anticapitalistic political ideas. A play on "trademark," *®™ark* satirized the problematic relationship between art philanthropy and artist activism. It purported to enlist activists, artists, and financiers around the declared goal of providing activists with a way of organizing that would prevent their exposure to liability law. Corporations, ®™ark's makers reasoned, were protected from their actions by such law: "®™ark company activists enjoy anonymity, limited liability, and increased exposure to resources and other activists" (®™ark, Inc. 2000a). Viewers who clicked through the website learned that ®™ark claimed to be a collaboration of activists and funders who wanted to find each other to "direct the flow of cultural capital." The website also emphasized the status of corporate personhood and suggested that groups of activists could be made more powerful simply by embracing the legal rights of corporate entities. ®™ark self-identified as a corporation for the purpose of social commentary.

In the context of this book, tactical media practitioners are of interest precisely because of their agnostic attitude toward whether they worked in art or science. Leopold and Rudolf Blaschka sought to be perceived as creating works relevant to science through the medium of glass, a material traditionally understood as artisanal. Berenice Abbott promoted photography as the appropriate tool to spread scientific ideas to the public. Tactical media practitioners used the graphical user interface of internet-enabled personal computers to compose their interventions, but they were less explicitly normative than the other artists mentioned in this volume regarding judgments that these tools were the correct instruments for the field. In this respect, tactical media practitioners positioned themselves outside the imagined art-science axis. For these actors, technical tools and artistic traditions were subordinated to their political stances, ends they pursued outside science and art communities.

Tactical media emerged in a world where control of messaging was fiercely contested. Whether their projects used internet-enabled means or newspaper spoofing or a host of other tactics, the watchword of these practitioners was participation: they called for, enlisted, and enacted participatory modes in bringing new parties into contact with a range of social and political issues (Raley 2009). These art-trained technology-using provocateurs applied their technical prowess and satirical creativity in ways that defied the categorization of their work as either art or science. As much as the Blaschkas and Abbott were dedicated to concepts of science and art that matched their agendas, tactical media practitioners drew practices from these two worlds but did not place themselves in either. They believed that their agenda was best served by not identifying with either knowledge community. Accordingly, study of the ways in which tactical media practitioners self-identified and self-situated affords a different perspective on art and science categories than is available by studying actors committed to the use of these categories.

POLITICS, PERFORMANCE, AND THE TECHNOSCIENCE OF ART

The contemporary World Wide Web is now filled with savvy corporate websites. Social media has brought about new forms of corporate reach: companies have turned away from smooth marketing and have attempted to reach consumers with the social touch of their peers. There was a moment during the 1990s' corporate expansion into the internet, however, when the difference between a personal home page and a major corporate or governmental website was smaller. Into that breach came a group of activists who worked from traditions of art inventions in politics and used their technical skills to create web pages exposing what they saw as the problems with corporations and public organizations both domestic and international.

We have hitherto seen how liminal spaces of art and science were occupied by works of glass and photography made to fit into scientific networks of natural history or physics. In contrast, tactical media spanned the borders of technology, science, art and politics. In art circles, technology and science blur into one another as mediums, and as subjects technoscience and technology are deeply entangled and impossible to disaggregate (Latour 1987). In the context of the history of computing, scholars such as Janet Abbate (1999, 2010, 2017) and Gerardo Con Diaz (2016) have shown the interconnectedness of computer science and computer hardware. Although this is hardly unique when comparing the sciences, state institutions such as the National Science Foundation did play a particularly well-documented role in building the infrastructure of the internet.

By the early 1990s, new institutions and older corporate entities previously not involved in infrastructure development were colonizing the internet for commerce. Tactical media practitioners sought to use the same tools and the new spaces around the World Wide Web to critique corporate interests and to raise awareness of the effects of separate uses of science and technology. In tactical media work, it is difficult to separate art from technoscience in a single project or even in an actor's own practice. For many tactical media artists, science and technology were interchangeable terms. Because these twin modes are coproduced and reliant on one another in a way that makes easy division impossible, tactical media artists tended to treat them as one. At its heart, tactical media is a critique of capitalism that employs corporate technical means to dispute the science and prescriptive social relations that they promote. These artworks included satirical corporate and political websites and environmental interventionist robotics, as well as forays into concerns around biological weapons systems and genetically modified foods. George Gessert has even proposed what he calls "genetic folk art," which involves the recognition of aesthetic practices related to breeding which are outside of contemporary understandings of genetic interventions (1993).

For the tactical media artist, technoscience and politics were never far from the creation and application of knowledge. Sheila Jasanoff (2010) held that only "settled" science or technology not currently under risk evaluation sees itself as nonpolitical. Scientists may or may not be aware that their data are political objects. Tactical media practitioners perceived the emerging science and technology of internet-enabled personal computing primarily as an instrument enabling novel political interventions in corporate power structures, not as the primary subject of critical analysis itself. In effect, however, these artists contributed implicit commentary on and alternative understandings of science and technology as epiphenomenal to their work.

To be sure, most tactical media practitioners drew inspiration mainly from traditions of political activism in the arts, often involving the use of humor and satire and concepts pioneered by the Situationist International (SI), a radical art movement associated with European art circles around Marxist, dada, and surrealist principles (B 1987). The selection of media as this community's medium of choice, however, raises the question of the determining properties and affordances of media technology famously broached by communication theorist Marshall McLuhan (1964). In their influential manifesto the "ABC of Tactical Media," published on *Nettime* in 1997, media theorists and practitioners David Garcia and Geert Lovink wrote that tactical media happened "when the cheap do it yourself media, made possible by the revolution in consumer electronics and expanded forms of distribution (from public access cable to the internet), are exploited by groups and individuals who feel aggrieved by or excluded from the wider culture" (1997).

In short, the qualities of the technoscience of the early internet, as well as a host of prosaic objects and artifacts, were central to tactical media practice. Practitioners used technologies to "hook" an audience, construct commentary, and create mythologies and characters. They also employed a concept of technological agency, including the technoscience of computing and biotechnologies, to create projects with varied standards of what counted as "working" to further their political agendas. In practice, the categories of rhetorical and material strategy combined in nearly every element of tactical media work and served to reinforce one another. Actions on the boundary of art and technoscience, what Amy Youngs (2000) called "smearing," confirm the STS concept that the boundaries between disciplines are built by actors with specific purposes, although a particular boundary may outlive a given purpose. For Garcia and Lovink, tactical media projects inherently crossed borders: "Tactical media is a qualified form of humanism . . . an antidote to the newly emerging forms of technocratic scientism . . . [it] crosses borders, connecting and rewiring a variety of disciplines" (1997).

Although tactical media work was done online, a significant level of organization and creation of the environment for new projects took place in-person at conferences such as the "Next Five Minutes," a media and politics festival founded in 1993, often cited as an origin point of organization and new projects in the tactical media movement. Tactical media often had an in-person element as the involved artists worked from offline relationships. The significant reach of tactical media programs, however, issued from the potential of websites to connect audiences and to give even audiences that came to know of the project through offline interactions a sense that these ideas were available to anyone with an internet connection.

METHOD AND CHAPTER OVERVIEW

Tactical media are ephemeral. The primary medium for much of this work and therefore the primary source for this project was the internet, which provided records of tactical media activities and served as a resource in my effort to contact interviewees. Internet materials are perishable, and tactical media projects make sense only in specific contexts. The projects were generally designed for immediate impact; therefore, although practitioners did document their own work and the interests of audiences sometimes led them to save ephemera from projects, the research materials were somewhat limited. By the time my research began, tactical media was already a historical movement, albeit one with practitioners who were still creating works based on the ideas of a socially engaged contemporary art movement. Other activists and artists are still drawing on their efforts as inspiration. Although we may not be accustomed to thinking of the 1990s as historical in terms of an art movement, in the case of tactical media many important early projects are ancient in terms of internet history, and these are limited to what has been archived. Another important resource was the online archive associated with the "Next Five Minutes" conference/festival on media, art, and politics, though it should be noted that the first such festival took place in 1993, before the era of the web. Because many of these works had a performance component or no longer exist on the internet, I conducted wide-ranging interviews in a variety of formats: face-to-face in offices and homes, by phone, via Skype, via e-mail, and through social media. I interviewed tactical media artists who were both directly and indirectly involved in tactical media as well as journalists and technology and media scholars with knowledge of the area.

In addition to interviewing tactical media practitioners themselves, I was able to interview several journalists who covered tactical media projects and a few people who remembered seeing the stories, though most were connected in some way to tactical media or to activists related to the issues that the projects were covering. Recollections of first encounters with certain individuals or groups may be blurred by time. In the tactical media community, however, misremembering is an important part of narrative-making. This project is not reliant on the specific moment of understanding or particularly interested in the accuracy of the historical moment at which ®™ark or the *Feral Robotic Dogs* came to be understood as a valuable project. To further complicate the matter, some of my interviewees took my research as a platform for continuing tactical media work. This point will be further detailed in the section on identity. Given the ambiguities inherent in narrative constructions, the presentation of the self-common in interview settings, and intentional identity manipulation, I have concentrated not on verifying the facts or these practitioners' claims but instead on the strategies and meanings that these actors are employing as part of their work.

®™ARK, THE YES MEN, AND THE BARBIE LIBERATION ORGANIZATION

The tactical media project ®™ark is well known in new media art circles and was long a model for tactical media work. This website was used to draw attention to the legal disputes surrounding *GWBush.org*, a website that popped up in searches for the G. W. Bush website and that mimicked and parodied the campaign web page. In actor network theory terms (Callon 1986), ®™ark was a key node in the tactical media network. It was at once a discrete project and a heuristic to learn about other similar projects, and it drew coverage in the mainstream media. ®™ark was founded in the early 1990s by two artist-professors, Igor Vamos (also working under the name Andy Bichlbaum of the culture-jamming activist group, a cofounder of the The Yes Men, and cofounder of ®™ark [as Ray Thomas]) and Jacques Servin (working with The Yes Men as Andy Bichlbaum). Vamos studied studio art at Reed College, where he founded a street theater group, and is currently Professor and Graduate Program Director in the Department of the Arts at Rensselaer Polytechnic Institute. Servin is a professor at the Parsons New School for Design. The two have long and illustrious tactical media careers. In their work, they have been adept at confusing the chronology of their projects, presumably to create connections between their work that allow viewers to consider their actions across time and, more practically, simply find other related projects across the media space.

These two men claim that their first action was to create the *Barbie Liberation Organization* (*BLO*) in 1993. This group alleged that Barbie dolls had had their voice boxes switched with the voice boxes of G. I. Joes in a gender role inversion designed to undermine the stereotypes of these toys; however, this action preceded the ®™ark website. The first confirmed culture jamming project was a hack of *SimCopter*. This video game was purportedly modified by the artists to replace animations of women placed in the game for sex appeal and referred to as "babes" with half-naked boys. Sometimes Servin claims his *SimCopter* work was inspired by ®™ark, at others, the opposite. ®™ark's references encourage readers to "search the web" for more information about projects such as *SimCopter*.

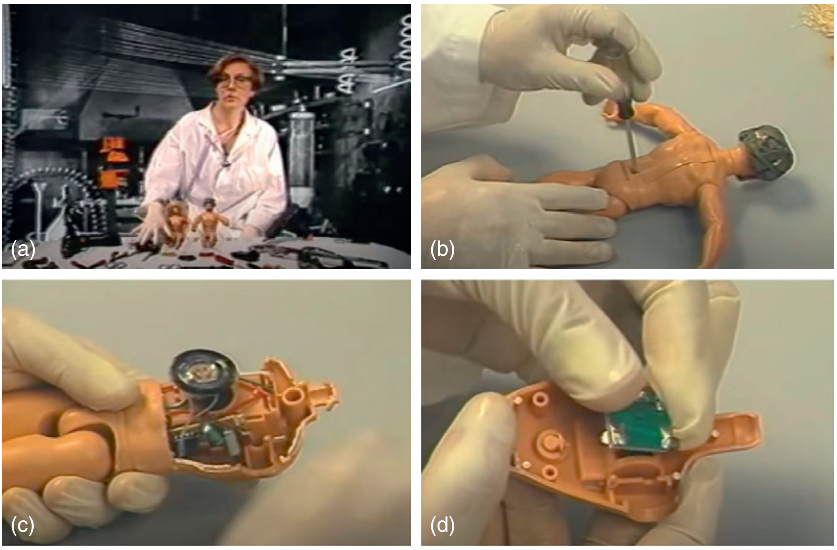
Though ®™ark, particularly in its original most active period in the 1990s, obscured the details of the origin of the concept of the piece, it is important to grasp its relationship to previous tactical media. Its membership overlapped with the well-known political performance group the The Yes Men. The Yes Men's call to action in the form of organizing people through an online presence could be understood to be a descendant of the organizational strategies put forward in ®™ark's mutual funds. This performance art group originated from a satirical World Trade Organization (WTO) website and became famous for stunts such as posing as a spokesman for Dow Chemical and accepting responsibility for the 1984 Bhopal disaster live on the BBC, which caused a brief drop in the company's stock price. An artwork by Steve Lambert, one of The Yes Men network's collaborators, involved many artists in creating and distributing a satirical *New York Times Special Edition* on the streets of New York (2008), which announced, among other things, the end of the Iraq War. The latter intervention received an honorable mention at the Prix Ars Electronica in the Hybrid Art category in 2009.

In the context of these works, Vamos and Servin are known by their pseudonyms, Mike Bonanno and Andy Bichlbaum, the two primary characters who make up The Yes Men. They engage in "identity correction," the practice of impersonation for the purposes of revealing corporate malfeasance. The Yes Men posed as spokesmen for the WTO and as industry leaders, infiltrating corporate events and suggesting a company's desire to correct a problem that it had created but had not solved or even admitted culpability for. The Yes Men claimed to represent a worldwide network of imposters and could be said to have begun their identity correction practice in elements of ®™ark, because its founders had collaborated on both projects. For ®™ark, Servin posed as Ray Thomas, chief executive officer of ®™ark. Similar to ®™ark's claim that they wanted to connect c*ultural workers* with financial capital, The Yes Men actively solicited donations.

As the *BLO*, these artists created a gender critique project (®™ark, Inc. 2000c). The action could be understood as a response to Mattel's 1992 release of Teen Talk Barbie, who could be triggered to play phrases such as "math class is tough," which received a swift response from outraged parents and feminists. The *BLO* intervention and press coverage from media outlets including CBS, NBC, ABC, and the television show *A Current Affair* occurred around the Christmas shopping season of 1993.[1] The group contacted media outlets offering to send them prepared videotapes and press releases reporting that Barbie and G. I. Joe dolls purchased from toy stores had had their voice boxes switched. The organization created an *NBC Nightly News* segment reporting on the altered Barbies, with clips from what they claimed were *A Current Affair* and CNN reports. The *BLO* claimed that it had "performed surgery" on around 300 voice boxes in toys for the holiday season and "shop gifted" (a play on "shoplifted") the toys back to stories to be purchased by consumers (figure 4.2).

According to the newscast, Hasbro, the maker of G. I. Joe, called the group's tactics "ridiculous," whereas Mattel reported that it had "received no complaints at all." The altered Barbies said things such as "dead men tell no tales," and the G. I. Joes asked "want to go shopping?" Although the degree of distribution of the altered toys was never clear, the *BLO* created an elaborate set of press releases, including a complete newscast covering its toy intervention, which encouraged the media to seek the toys and interviews with children who might have received them. The *BLO* also produced a promotional video in which Barbie speaks and a newscast showcasing a new anchor discussing various aspects of the Barbie intervention. The "Toy Tampering" story was covered by an NBC affiliate in Albany, New York (figure 4.3). In their *NewSpeak* documentary, the *BLO* included clips of the project as covered by a range of media outlets (figure 4.4) and interviews with children (figure 4.5) about what they thought of receiving toys with switched voice boxes.

®™ark claimed the *BLO* stunt as its first prank, but the exact timeline is unclear because *BLO* was founded in 1993, before ®™ark existed as a website. Other accounts state that the first ®™ark-sponsored project was



4.2 Dr. Christa Erickson, science correspondent, demonstrating the method for the *Barbie Liberation Organization*'s voice box switch surgery. *Source:* Video still from "Operation NewSpeak," documenting the activities of the *Barbie Liberation Organization*. 1993.

TOY TAMPERING

4.3 Ed Dague covers "Toy Tampering" on WNYT-News Channel 13, NBC affiliate, Albany, NY. *Source:* Video still from "*Operation NewSpeak,*" documenting the activities of the *Barbie Liberation Organization*. 1993.

PRODUCED BY
THE BLO
AND
CBS
ABC
NBC
CNN
THE SIMPSONS
THE TONIGHT SHOW
A CURRENT AFFAIR

4.4 Barbie Liberation Organization newscaster Mike Real talks with Barbie and G. I. Joe. *Source:* Video still from "*Operation NewSpeak,*" documenting the activities of the *Barbie Liberation Organization*. 1993.

4.5 Children Zack Zelin and Hannah Henze are interviewed about their experiences with the voicebox-switched G. I. Joe. *Source:* Video still from "*Operation NewSpeak,*" documenting the activities of the *Barbie Liberation Organization*. 1993.

Servin's 1996 hack of the Maxis video game *SimCopter* from the Sims franchise. This hack was an Easter egg, according to the artist's press release, which meant that on certain dates of personal value to the programmer, the hack generated "himbos" (a pun on "bimbos"), who were men in swim trunks who appeared on the screen and kissed. Whether these particular acts occurred before or after ®™ark, they are all remembered as part of the history that led to the same activists forming The Yes Men. The success of a tactical media project as a political influence is partly based on the number of people that the project reaches, and this is often tied to being taken up by major media outlets. ®™ark was quite successful in its pursuit of media attention. In addition to its online and art world coverage, *National Public Radio* repeatedly covered ®™ark activities (Karr 2000; Rushkoff 1999). The *New York Times* has reported its exploits (Quart 2007), and *CNN.com* referred to their "denial of service" attacks against *eToys.com* as grounds for "e-commerce sites to keep their defenses sharp" (Messmer 1999). Most of the informants with whom I spoke, even those who opposed some of ®™ark's tactics, praised its work as being thorough and clever. Interviewees frequently cited humor as part of the power of ®™ark. People passed on links and information to friends for satirical value and to reinforce shared political beliefs. This do-it-yourself art creation and propagation is an interesting aspect of tactical media work; it requires some effort on the part of the viewer. It is not a form of photorealism that indicates whether a project is or is not an operative image. Instead, the context of the object's deployment determines which rhetorical strategies (photos, drawings, logos) would most likely convince an audience that it is what it claims to be. The site is effective first through the audience's mistaking it for the real thing, but as the website subverts expectations, on reflection the viewer can see it as an effective parody.

CRITICAL ART ENSEMBLE

The Critical Art Ensemble (CAE) is one of the best-known groups of tactical media artists: they shaped the field, and their work extended beyond the genre and helped create new forms of contemporary political interventions from an artistic perspective. This technically skilled artist collective has created a number of tactical media projects, which they define as situational, ephemeral, and in opposition to authoritarian, particularly capitalist, institutional regimes. CAE holds workshops to teach others about tactical media, which has further extended its reach. Formed in 1987, prior to the explosion of tactical media, the group influenced the development of artists working with tactical media and also used tactics now associated with tactical media themselves. The group's six core members (Steve Kurtz, Steve Barnes, Dorian Burr, Ricardo Dominguez, Beverly Schlee, and Hope Kurtz) produced important installations in a variety of media. CAE projects routinely require many different technical skills and know-how because they have worked with electronics, biological materials, and digital art. One project was focused on the politics of names and proposed a dual renaming of Victoria Square in Adelaide, Australia (which some local people wanted to rename using an Aboriginal name). The project was accomplished by changing the signs overnight. Though the new signs were removed, the city council then followed the suggestion and gave the square two names, officially adding the name of the aboriginal leader "Tarndanyungga" to its original title (Triscott 2009).

CAE published important texts on art, science, and technology (1994; 1996; 1998; 2001; 2002; 2006; 2012). Detailed manifestos explaining the intent of tactical media artists and their philosophies can sometimes be difficult to come by, so CAE's extensive writing, which has been made widely available, have been influential in the field.[2] CAE's work is anticapitalist and reaches out to or includes local populations to involve more people in political art. In 2004, the group received a great deal of media coverage when Steve Kurtz, a member of CAE, was arrested in Buffalo in conjunction with a post-911 terrorist investigation. Kurtz was working with biological materials in his home as part of his work on genetically modified organisms in agriculture for an installation at the Massachusetts Museum of Contemporary Art (Wilson 2008). Tragically, Kurtz's artist-wife Hope, also of the CAE, had suffered a fatal heart event from her congenital heart failure, during which the emergency services were called, but sadly Hope Kurtz passed away. Meanwhile the paramedics immediately notified the police of the laboratory setup in the Kurtz home. The Joint Terrorism Task Force swooped in, detaining Kurtz on suspicion of bioterrorism. The FBI, the Department of Defense, and Homeland Security entered and sealed off Kurtz home and seized materials including those for the couple's bioart exhibitions. The Buffalo, Although Kurtz was never indicted on bioterrorism charges, he was charged with mail fraud, sparking an outcry in the artistic community and a fundraising effort for his legal bills. Eventually, in 2008, all charges were dismissed because the indictment for mail and wire fraud was ruled "insufficient on its face" by Judge Richard Arcara. The Department of Justice did not attempt to indict Kurtz again.[3]

PREEMPTIVE MEDIA

As the worldwide but one-way web faded in the late 1990s, new concerns about surveillance and the exchange of individual information emerged. Tactical media practitioners turned their skills on these problems and began to produce works to make the public aware of the privacy concerns associated with data information exchange in the context of commerce and government data collection. A 2004 exhibition by Preemptive Media called *Swipe* (Singer, da Costa, and Schulte 2004, Singer 2016) attempted to make people aware of how their personal information is linked to ID cards and what information is public or available on the open market by pay subscription. Swipe functioned as situational performance art. The project consisted of a bar set up in conjunction with an art opening at a museum as a short-term installation. As expected at museum openings, the bar offered a complimentary drink to each patron. When the patron presented identification, ostensibly for age verification, the strip on the back of the patron's identification card was swiped. Using commercially available databases, the artists created a printout of the patron's personal information, which was served along with the patron's drink (figure 4.6).

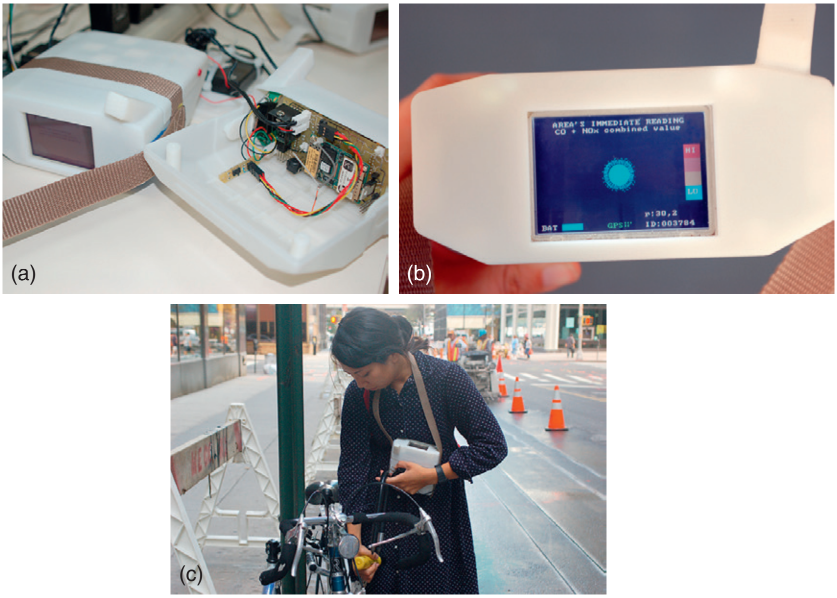
This project required both an intimate knowledge of where to find what artist Brooke Singer has called digital doppelgangers (2002)—that is, the traces of digital information that can be combined to create a picture of individuals and their activities—and the technical skills to make the installation run smoothly and prevent backups of data orders. Singer also felt that their best audience would consist of people who were naive to the artwork until their data were served to them. Particularly as the project became better known, the reactions of the audience to the work

4.6 Preemptive Media (Beatriz da Costa, Jamie Schulte, and Brooke Singer), *Swipe*, bar and toolkit, 2004.

changed from understanding the political message—that their information could be accessed by a stranger—to being simply curious about what the artists could find out about the patrons.

In 2006, Preemptive Media turned its technical prowess to local environmental issues through the project *Area's Immediate Reading* (*AIR*), which offered participants in workshops in cities such as New York, Pittsburgh, and San Francisco a chance to use a handheld device to map air pollution in their area. Although many tactical media projects attempted to shape agreed-upon public knowledge, *AIR* developed a new method of air quality testing. It exposed the deficiency of the traditional method of positioning stationary sensors on rooftops or high poles in parks while also producing new air quality figures to be considered. Instead, participants explored their immediate environments looking for air contaminants using devices created in *AIR* workshops (figure 4.7).

A related project (*Pigeonblog*, 2006–2008) was a collaboration between da Costa, then an assistant professor at the University of California at



4.7 Preemptive Media (Beatriz da Costa, Jamie Schulte, and Brooke Singer), *AIR*, devices and workshops, 2006.

Irvine, and colleagues at the university. Da Costa, who sadly passed away in 2012, straddled the engineering and the former Arts, Computation and Engineering (ACE) program led by Simon Penny. It is also worth noting that da Costa was a former member of and subsequent collaborator with the CAE. The *Pigeonblog* was an effort to visualize in real time pollution on a website that would be widely accessible to attract attention to local environmental issues. The work involved strapping air pollution sensors and global positioning system (GPS) backpacks onto pigeons. Observing that standard sensors remain stationary, the artists hoped that the birds might capture more accurate data about air pollution in southern California. A map of pigeon sensor outputs is available on the internet to publicize issues of air pollution for local communities (da Costa 2006).

In 2004–2005, Preemptive Media launched *Zapped!,* which used the same media that they had employed in *AIR*, namely a technical workshop and internet-based campaign to let people know about the project. *Zapped!* examined the increasing use of radiofrequency identification (RFID) tags in a host of surveillance-related applications by Walmart, the

4.8 Preemptive Media (Beatriz da Costa, Jamie Schulte, and Brooke Singer), *Zapped!,* Madagascan Jam & Hissing Roach with reprogrammed RFID tag, 2004–2005.

Department of Defense, and the U. S. Food and Drug Administration. As part of their workshops, participants were invited "to learn about the RFID system and to make their own RFID keychain detector that will ring, vibrate or light up when a RFID reader is within range and scanning the airwaves for data" (Preemptive Media 2005). Among other possible interventions, Preemptive Media suggested that cockroaches with reprogrammed RFID tags could be released into stores or warehouses to confuse the tagging system (figure 4.8).

MARK SHEPARD

Mark Shepard is an artist who works with technologies of location. His work considers the ways in which these often top-down technologies could work from the bottom up. Shepard's work requires proficiency in programming as well as electronic systems design and troubleshooting. His 2007–2012 project *Tactical Sound Garden* was a free software program that allowed wireless device users to attach sounds to geographic locations within a given space using a GPS system. For example, a user might tag a courthouse with a political message that others could hear via their mobile devices and software as they passed by. Passers-by could choose to listen to the message or add one of their own. This project enabled a community of users to enter and edit sounds of their choosing to create a public sound garden, while potentially evading the gaze of authorities and nonusers.

NATALIE JEREMIJENKO

Natalie Jeremijenko works at the borders of science, technology, STS, and political art and has created several projects that require technical and scientific expertise, ranging from cloning to robotics. An investigation of genetic dynamics called *OneTrees* involved planting cloned trees in different locations around the San Francisco Bay area (2000). Plant clones are very common, but by positioning the work as a piece about nature versus nurture, Jeremijenko provoked questions about the concept of clones more broadly. Her works function as tactical media because of their situational nature and emphasis on public involvement. As part of her Bureau of Inverse Technology (BIT), she created *Feral Robotic Dogs* (2006), which drew attention to environmental issues. At workshops, the public was invited to learn to hack off-the-shelf robotic dogs to add pollution sensors so that they could use their dogs to scan local environments for toxins. Jeremijenko also has a "health clinic" in New York City that offers prescriptions for healing the earth.

The *Feral Robotic Dogs* project involved a combination of tactical thought experiment and design project. Like *Swipe* and *Pigeon Blog*, it included both physical objects and a web presence. The piece involved considering what it would be like if then-popular toy robotic dogs were, in fact, "motile" beings, waiting in our homes and offices to someday take over the world. For the design portion of the project, the dogs were outfitted with sensors to locate pollution, and students and community members were encouraged to deploy them around their neighborhoods to check for environmental contaminants. The project also tapped into popular ideas (and fears) about dogs, suggesting that they might be able to develop pack behavior, run loose, and collectively map their surroundings using GPS technology. Jeremijenko created media events around them that brought attention to issues about pollution and how the public receives and understands pollution issues.

Jeremijenko is deliberate in the positioning of her work. In art circles, she is accepted as an artist. To date, Jeremijenko has published neither peer-reviewed articles nor books about her work within STS or human-computer interaction (HCI) contexts, yet she is sometimes perceived as a scholarly researcher in these areas. In STS circles, she is perceived as an activist science studies scholar (Weiser and Brown 1995). In interactions with the human–computer interaction community, she is accepted as a human-computing interaction researcher, possibly owing to her work at Xerox PARC in the artist residency program (PAIR), where she created the *Live Wire* experiment. *Live Wire* (or *Dangling String*) was a 1995 piece, theorized by Weiser, who oversaw Jeremijenko's residency, as a "calm technology." It was an ambient indicator of internet traffic: it consisted of a piece of string attached to a stepper motor and controlled by a local area network connection so that network activity caused the string to twitch, creating an unobtrusive indication of internet traffic.

Her acceptance in research communities opens possibilities for new artworks and theoretical engagements, and she has noted the usefulness of the categorization of her work. She is aware of the power to influence the labels that will be used to describe her and her projects and the importance of rhetoric in naming her projects. This power to frame her work allows her to influence the terms by which her work will be understood and its potential interpretations. For example, her *Environmental Health Clinic*, an academic studio-lab at New York University, where she is a professor, plays on the conventions of environmental and health interventions to offer people prescriptions for improving their community's environment. Positioning this artistic intervention as a clinic has the effect of strengthening the case that there are individual actions that can be taken that will result in improvements in problems with environmental causes.

POSITIONING IDENTITIES

With these examples of tactical media in mind, let us turn to a discussion of the ways in which the involved actors have positioned their work through creating identities for themselves. The issue of identity and of the origin and reliability of information is central to tactical media work. ®™ark and other tactical media projects produce irony by creating the appearance that things are other than they seem. Using technology and carefully crafted identities to make it appear that the organizations that they claim to represent are large and sophisticated, tactical media artists marshal a variety of techniques for their work. The power of these works is possible in part because of the way in which these actors present themselves and conceive of the resources available for their work.

Tactical media artists are very aware of ways in which they can compose their own identities. Self-fashioning is a basic tool of their trade. Because their projects often have a performance component, physical appearance is one cue for how the audience should understand the artists. When the CAE works with biological materials, they often wear lab coats, though sometimes, as in the case of CAE's *The Cult of the New Eve*—a feminist critique of the human genome project—they don matching red hoodies with the project's insignia. In some cases, the artists even talk about their self-fashioning. The Yes Men documentary spends significant time showing the preparations required for Servin to pose as a WTO representative. This involves wearing a suit, getting a haircut, and buying a counterfeit Rolex watch. Given that costuming is a part of the everyday world and flexible identities of The Yes Men, we need to look beyond surface markers to investigate the ways in which tactical media artists think about their identities and the identity of their social group. Tactical media artists actively construct their identities. This self-fashioning includes maintaining a mythology that is a history of selected influences identified by its artists.

Erving Goffman's theories (1959) of identity performance can offer some direction in understanding presentations of self that are available to interviewers in various contexts: ". . . when an individual appears before others he will have many motives for trying to control the impression they receive of the situation . . . [t]he issues dealt with by stagecraft and stage management are sometimes trivial but they are quite general; they seem to occur everywhere in social life" (26). Goffman's observations bear on both interviews and the creation of personas. These sometimes-fictionalized identities are created to designate the intentionality involved in identity performance. Goffman has shown us that some of this behavior is always in play in self-presentation; tactical media artists sometimes create identities intentionally for the purpose of a tactical media project. Judith Butler's work on performativity supports the idea that identities, like categories, are constructed rather than being innate to an individual (1990). I refer to these identities as "characters" to signal that these exist in the context of tactical media.

For some tactical media artists, the idea of a performing identity is made explicit: they are literally "performing" the identities of others through all available means. This may be done to appear to be an expert on a topic or to belong to a particular social group, either artists or scientists. In the most extreme version, the performance may involve mimicking a persona associated with a specific group or even a specific individual. The identity mimicry is sometimes as simple as giving a false name but may be as subtle as a clothing choice. This has the effect of unwinding categories and undermining what these artists might see as the too easy boxing of people. In either case, a combination of rhetorical devices and material objects suggests and then supports the idea that the person in question is a specific character. For example, to locate a speaker for a conference, an organization might approach one of The Yes Men's spoof websites. The Yes Men deploy their website as evidence of the validity of their claim to belong to a specified organization. The authority that the website provides allows artists to respond on their own terms and in their own framing language to journalists' inquiries.

Authenticity could be considered a special problem in the case of people who intentionally interact with media and interviewers in persona or characters created for the purposes of their artwork. The internet poses some specific challenges in this regard, though Goffman addressed the majority of these issues in *The Presentation of Self in Everyday Life* (1956). He argued that in the dramaturgy of social situations, individuals made use of *sign vehicles*, an idea based on Charles Sanders Peirce's semiotic theory of the same name (1883). Goffman explained that in the social context, these were coded ways in which individuals transmitted information to others about identities; of course such identity signaling persists online, albeit through some new as well as old codes. Christine Hine (2000) has explored the issue of authenticity on the internet. She pointed out that in the internet context, different markers may be used to judge authenticity. Some may have a clear correspondence to the traditional interview setting, whereas others are specific to online presence. Sherry Turkle (1995) held that interactions with computers were no longer about giving machines commands but now deal with relationships. The internet may be viewed as an identity play space, and experiments with identity are frequently welcomed by groups of users. Hine proposed that instead of inquiring about whether persons known via the internet are who they claim to be or attempting to judge whether internet presence mirrors or even maps offline identities, ethnographers should focus on how internet culture is known and organized on its own terms. It should be noted that many of the problems ascribed to the internet are also the case with any text: that authenticity is a rhetorical strategy present to varying degrees across forms of communication, and it should not be assumed that the authentication issues present across the internet are solely the result of the technologies in question.

One of the more interesting situations of authenticity and radical self-positioning that I encountered was an interviewee who spoke to me about interactions with a person whom I knew to be a character created by ®™ark. Pretending to be someone else or connected to a group that you portray as larger or more important than it is for performance effect is an important tactical media strategy, but the degree to which this individual understood the person being discussed as an invention of tactical media or as an actual person involved in the projects of ®™ark was never clear. This has the practical effect of making the website closer to a corporation in its facelessness and makes it easier to imagine a broad network of tactical media practitioners working together to create these outputs. If we take the actions of these informants as a version of Goffman's observations about maintaining a public persona, we can understand that performing a different identity in different contexts is similar to creating an entirely distinct persona in each. In the case of ®™ark, additional characters, for example a chief executive officer, add legitimacy to the project's claim that the organization acts as a corporate entity. Even more frequent in my interviews was a sort of passive allowing of misinformation. Interviewees did not offer additional incorrect information but enabled the belief of the listener in the claims of a fictive person or confirmed parts of stories about ®™ark. This was signaled by phrases such as "a person who called himself" or "the person you are calling" or even "a person who goes by" or "a person who is called." In these ways I was made aware of and could respond about relevant actors without directly exposing their knowledge of a particular actor's character.

Goffman's 1952 article "On Cooling the Mark Out" addresses the feeling that some will have when faced with facts that do not quite add up.

Although some projects that involve deceit are meant to come to a clear end when everyone is made aware of the "con," often the "marks" of these projects realize that they have been had before the announcement of the con and may for their own reasons lead others along into the ploy. Such was the case for one journalist I spoke to, who confessed to not making apparent to the public what he suspected because he liked the game that the tactical media artists were playing and furthermore was sympathetic to their political cause. Instead of needing the "operator" to console them for their erroneous thinking, these marks joined the cause in a situation analogous to Stockholm syndrome, in which those who might have been victims of the ploy believe themselves to have become insiders, capable of assisting in the cause that they were once set to experience as an outsider. Although affordances of technological communication created as part of a strategy on the part of the interviewee may be nothing new in Goffman's terms, they certainly put the interviewer at an information disadvantage.

In another example, The Yes Men, active according to their own account since 1996, have become famous for what they call *identity corrections*. In these situations, tactical media artists pose in public as representatives of institutions or as people who they are not, to say things that they believe reflect the true sentiments of the people that they depict, things that those individuals would never say directly. These inadmissible truths might be suggested through fictionalized means. For example, The Yes Men gave a series of lectures at conferences posing as representatives of the WTO, in which they suggested the *Post Consumer Waste Recycling Program*. In a *Soylent Green*–style twist, the "solution" involved the recycling of an eaten hamburger by passing the waste on to another consumer. The Yes Men's presentation was hardly noticed by listeners, despite outrageous graphics (including the suggestion that a hamburger could be eaten more than ten times), until they presented their idea to an outraged college classroom audience. On one occasion, their presentation included a demonstration of a suit containing the Employee Visualization Appendage for promoting worker productivity. The suit could open to unfurl a large metallic phallus with a screen for tracking workers from a distance. These identity-correcting actions may be seen as being similar to websites supported and promoted by ®™ark, such as *gwbush.com*, an ®™ark website that appeared to be a campaign website but was critical of the candidate, often through use of his own words. Much to the artists' delight—because to them all press is art—Bush campaign lawyers eventually sent a cease-and-desist letter, which ®™ark posted on its website.

Individuals wishing to appear to be other people or, in some cases, a large group or institution benefit from affordances such as technological communication devices that can mask the individual. As artist Paul Vanouse put it, "That was the thing about the internet and earlier technologies like the telephone; you never quite knew what you were dealing with . . . the amazing thing about ®™ark was the kind of authority they managed to have, even though it was just run by a few people" (2007). Adding additional phone lines that run to a single office or having additional web pages can give the impression of an expansive project. This strategy may be somewhat more common than one might think.[4] A combination of rhetorical misdirection and materials offered to bolster the credibility of such misdirection made ®™ark's success possible.

MYTHOLOGY MEDIA

Tactical media artists have a variety of ways of talking about their history, which I refer to as *mythology* to designate the way in which the histories are designed as a tool for reading tactical media work. Howard Becker discusses making a mythology for one's practice in *Art Worlds* (1982), in which he describes the network of art in terms that would be familiar to sociologists of science. According to Becker, artists construct for themselves genealogies and histories of influence that credit their predecessors and suggest a trajectory.

So common is this idea in art that we may expect a kind of feedback loop in which artists, aware of the idea, set out already knowing that their influences can be selected and that their work will be read through those influences. Tactical media artists may strategically enroll predecessors as influences to describe the work that they wish to be associated with or to build on, or even to be part of a critique. This myth making is a prominent rhetorical strategy in tactical media, one that relies heavily on the materials created by the predecessors claimed as lineage to be convincing. The tactical media artists have a variety of stories about the major events and influences around tactical media. Most of my interviewees think of themselves with a specific history, one that includes texts such as those of the Situationists (Ball 1987), Michel de Certeau's *The Practice of Everyday Life*, and Terry Southern's absurdist novel *Magic Christian*.

An important antecedent of tactical media was the Situationist International organization (SI, 1957–1972). The SI sought to facilitate labor strikes and other public demonstrations, playing an important role in the events of May 1968 in France, when seven weeks of civil unrest led to a brief halt of the French economy and the flight of President Charles de Gaulle to Baden-Baden, Germany to discuss possible military strategies before returning to France. Situationist activities included actions in everyday society, and, beginning in June 1958, the publication of the *Internationale Situationiste*. The group's publications and actions may be considered public art because they were political critiques inspired by the avant-garde. The group was interested in setting up situations to fulfill desire ("each person must seek what he loves") and as an alternative to capitalism. This interest in setting up the proper environment, or situation, gave the group its name. Tactical media draws some of its character from the Situationist movement, including its interest in intervening in everyday life and its tendency toward the playful.

French Marxist theorist Guy Debord, the organizer of the first SI meeting, wrote some of the most recognized Situationist texts, including *the Society of the Spectacle*. Debord, as translated by Ken Knabb as part of his Bureau of Public Secrets (www.bopsecrets.org), began with the proclamation that "Everything that was directly lived has receded into a representation" (Debord and Knabb 2014). Situationist slogans appeared as graffiti around Paris preceding the events of May 1968.

Central to the Situationist critique of advanced capitalism was the notion that technologies were producing spectacles that were increasingly replacing active social interactions with passive viewership and creating a never-ending present. It is important for our purposes to note that SI did not oppose technology; rather their opposition was to use technology to create and maintain spectacles, thereby creating passive workers and consumers. Similarly, tactical media practitioners have not taken a position in opposition to media technologies but rather to the way in which they have been used.

SI and tactical media both engaged in attempts to turn the spectacle on itself. Commandeering media through culture jamming and hacktivism is seen as an antidote to the misdirection of mass technologies for capitalist purposes. This use of mass technologies to provoke change depends on the shared equation that media attention does indeed garner public willpower rather than implicating the public in yet more viewership. Tactical media projects create alternative spectacles by drawing attention to the narrative flow of the never-ending present and redirecting it toward unexpected storylines, such as the funding of anticapitalistic actions or Barbies with G. I. Joe voice boxes. In some respects, ®™ark can be seen as an example of the Situationist concept of détournement (a variation on a previous work that comes to mean the opposite of the original) because it began with the original genre of the corporate website but, as it is experienced, demonstrates quite the opposite impulses.

PRACTICES OF EVERYDAY LIFE

Michel de Certeau (1984) distinguished between the strategic and the tactical. Strategic maneuvers can be thought of as official and approved actions brought about by institutions; tactical behaviors are those behaviors available to individuals to deflect strategies. De Certeau proposes that tactical behaviors cannot be fully known but that social sciences should at least attempt to understand what can be known about them. It is important in his conception of these two types of behavior that the tactical does not actually try to destroy the strategic. Instead, it seeks to empower the less powerful and make the place of the everyman in society "habitable." Garcia and Lovink wrote that tactical media drew the *tactical* in its name from this concept. Tactical media practitioners tried to increase the number of tactical actions taken, particularly against corporations (1997). In this model, the power of tactical media is thought to derive in part from its diffuse nature, though CAE has written that capitalist institutions have become equally diffuse.

ARTISTIC INFLUENCES: THE MAGIC CHRISTIAN FUND

Among the many funds at ®™ark is The Magic Christian Fund, which points to the longer history of art interventions, particularly against capitalism. The fund is named for American author Terry Southern's

The Magic Christian (1959), which follows the adventures of Guy Grand, a wealthy and colorful character who is continually creating elaborate pranks targeted at everyone from train food vendors to the entertainment and advertising industries. Although Grand is not always a sympathetic hero, his jokes reveal others' greed and self-interest. The novel was the inspiration for one of ®™ark's funds, which are web pages where "investors" (artists, the general public) can suggest ideas for actions and offer resources for carrying them out.

®™ark's creators were inspired by Southern's novel, so they asked his son, Nile, a writer and filmmaker, to act as fund manager for *The Magic Christian Fund*. The fund suggested such projects as creating pornographic annual reports for a major company (Proctor & Gamble or Time Warner were suggested) with charts "utilizing various body parts as indicators" and mailing these reports to stockholders (®™ark, Inc. 2000b). Tactical media artists draw on these works both rhetorically, as standing in for their history and connecting them to a larger body of activism, and specifically, by drawing ideas from them. For example, in Southern's novel, Guy Grand engages in a variety of subversive and often hilarious interventions. The wealthy entrepreneur pays a soap opera actor to deviate from the script, comment on the poor quality of the program, and walk off the set. This spawns the same action by other actors until the show is actually a success because the audience is enraptured by the deviation from the genre. This type of intervention and in particular the copycat syndrome that follows is surely the holy grail of tactical media: the possibility that the interventionist act will result in waves of change.

As Stephen Wilson explains in *Art + Science Now* (2010), it is impossible to separate contemporary art practice aimed at political outcomes from the happenings and performance art of the previous five decades. Although none of the artists I spoke with specifically evoked puppeteer protestors or the theatrical actions of Greenpeace, these types of interventions are implicitly available as resources for tactical media artists. The countercultural Youth International Party (YIP/Yippies) and related groups engaged in street theater and political pranks, including advancing a pig ("Pigasus") for U. S. president at the 1968 Democratic Convention in Chicago (Kusch 2008, 60). The trial of the offending party members was covered extensively across a range of media including *The*

Washington Post, the Associated Press, and the *Chicago Sunday Times*. Publications such as YIP co-founder Abbie Hoffman's *Steal This Book* (1971) were part of the cultural scene from which tactical media emerged.

Like those whom they count as predecessors, tactical media artists weigh in on the side of leftist politics. I asked several of my interviewees if there are any conservative tactical media projects. Surprisingly, two interviewees suggested with irony the same pair of examples: President Bush's strategist Karl Rove and FOX News. These informants were implying that the tactics of pretending by offering imaginary facts were employed with less irony by public figures and news outlets for their political purposes. Another suggested that some of the work of antiabortion advocates has also taken the form of tactical media projects. Rove's work may not quite approach the notoriety of that of Donald Segretti (sometimes described as Rove's protégé), who, after executing a series of "dirty tricks" during the 1972 Nixon campaign was jailed as a Watergate conspirator. Rove seems to have incorporated some ideas from the dirty tricks mentality, however: in politics the end of winning is often worth the means used to get there. Tactical media practitioners use tactics that Segretti and Rove would surely recognize. One might fairly ask how this question might be answered in light of the Trump presidency and its accusations of "fake news."

For many tactical media artists, evoking the history of the Situationists and Southern's novel helps to project the philosophies and histories with which tactical media artists want to be associated. The material presence of those works combined with practitioner interest in avant-garde arts allows tactical media artists to make the case that their work has a political lineage, despite individual actors' backgrounds in art or use of scientific skills.

MIXING FICTION

Many tactical media artists draw on fictional resources as part of their practice. Not dissimilar from creating personas to further a project, fiction and nonfiction are considered resources to be drawn on for the work. For the science studies analyst, this is an unusual situation. Most sciences, and most of the subjects that science studies focus on, may take in constructions and the fictional, but they do so either unknowingly or as part of a construction that is believed to be true, at least by the actors. Intentional deceit and false findings in science are not uncommon, but they are considered breaches of scientific ethics. For artists in this area, the cleverness of the deception is part of the art, and the ethics are best served by exposing problems through their art. For the tactical media artist, definitions of the real are complicated. For the creators of *BLO*, for example, the issues around gender are so real and pressing that whether Barbie voice boxes were switched for G. I. Joe voice boxes become irrelevant to their projects.

This is slightly different from Latour's idea that observation is theory dependent (1987; Hanson 1958). If tactical media actors were asked, they might suggest that the fictions were purported by, for example, large corporations, whereas the truths were exposed by a project such as ®™ark. For tactical media artists, this difference is simply inconsequential to the goals of their project. They see useful elements in both these categories and are happy to employ either. Their difference in beliefs affects their observation, not so much through the blurring of fact and fiction as through the expanse of resources drawn from fiction and nonfiction, sources that they see as equally available to enact their projects.

MATERIAL PRACTICES

Like art of a conceptual nature such as these tactical media works, in many cases the scientific work is in the proposition itself. Max Black (1962) differentiated between the mathematically possible and the physically possible in models. As in the theory of natural selection, in some cases the work of science is done by proposing theories rather than creating physical objects (aside from the text). Conceptual art seems to work in a similar manner. If an artist is able to present an idea without the presence of the embodied object, event, or situation, then does it matter if artists embody these elements for their projects at all? In short, is it necessary to make things or are ideas enough? These tactical media projects are in some ways similar to planned buildings that are not built. Credit is awarded precisely for the creation of a project whose execution is, in fact, its plans.

Some tactical media artists do create tangible objects, whereas others do not. Many create “evidence” of objects that did not exist. ®™ark was a website: it was not a corporation in the sense of a group of people who occupy a set of buildings in a business park. It proposed an organizational structure like the structures used by the corporations it attempted to undermine, but it did not exist in a group of cubicles. Its influence flowed from its ideas publicized via its web content and media actions. Is the idea of ®™ark enough? Or is something gained by having the website available to be explored? Other tactical media projects have engaged in information campaigns directed at media outlets. They may have created artifacts such as press releases, but the media presentation and subsequent public reaction constitute the execution of the work.

Another major tactical media project that created only websites without accompanying artifacts focused on surveillance and pregnancy. *SmartMom* (Faith Wilding; see subRosa 2000) is a website tactical media project built by the feminist art collective subRosa, “an artists’ collective that produces performative and new media projects that critique the relationships between digital technologies, biotechnologies and women’s bodies/lives/work.” The work consists of a series of pages advertising and explaining “SmartMom,” a pregnancy suit based on military technology that would enable the surveillance of pregnant women and fetuses. As the website explains, “pregnant women can wear a suit to monitor their every move and bodily function, and also that of their fetus’ . . . the problem has been that pregnant and birthing women who are moving freely among the general population are hard to control and surveille at all times. While doctors try to regulate the lives, activities, and diets of their patients, women tend to be resistant to this form of control and many of them habitually disobey doctor’s orders and lie about what they have been up to.”

Like most tactical media projects, the work is conceptual. An actual SmartMom suit was never built, even though the page includes drawings of the suits and descriptions of their usefulness and special features. The entire project is just an idea. There is no embodied project, though it might be argued that there is an embodied idea in the form of the descriptive website. The purpose of this project appears to be served simply by releasing the idea that such a surveillance technology could exist.

The idea of thinking of the medical practice of obstetrics in conjunction with surveillance has been researched by Emily Martin (1987), Evelyn Fox Keller (1990), and others. Akrich and Pasveer compared degrees of surveillance during childbirth in French and Dutch subjects and found that expectations played a major role in the mother's degree of satisfaction with her experience (2000). Whereas surveillance and obstetrics are the subject of subRosa and these science studies scholars' work, their orientation toward critique is different. SmartMom takes these ideas to the extreme, producing a parody, whereas science studies scholars expose the issues of this way of thinking through detailed accounts of the ways in which this surveillance technique works.

®™ark functions on its rhetorical power to suggest that people could alter gas tanks, add characters to video games, or do a host of other activities to draw public attention to political issues, whether or not these projects were ever physically completed as suggested. How far back can this chain extend? Does it even matter whether the ®™ark page existed, or is it a complete work if the idea of a revolutionary website that appeared to be a corporate webpage was circulated? Marc Böhlen (2007), creator of the tactical media website RealTechSupport (realtechsupport.org) and professor of art at the State University of New York at Buffalo, is critical of approaches that do not involve, as he puts it, "real tangible things." When asked about trends in tactical media, Böhlen argued that people are more likely to respond to projects that involve embodied technologies. "I imagine that people will want more in the future; more [. . .] real tangible things and obvious change" (2007). Böhlen was concerned that media frenzies around ®™ark would not equate to actual changes in politics, capitalism, or everyday life. ®™ark's demonstrations were not expected to create immediate change but rather were bids for demonstrating what is possible and encouraging their political comrades with the idea that interventions can be completed.

Nile Southern, a "mutual fund manager" for ®™ark, echoes Böhlen's sentiment that actual social change should be the future goal of tactical media projects. In describing the type of projects that he saw as the future of tactical media and ®™ark, he spoke of the possibility of enrolling actors already installed in positions of power to do the kinds of things described in the ®™ark mutual fund pages. Southern believes that one aspect of a great tactical media project is to produce concrete change in the world. To this end, he imagined that the greatest possible project would be cooperation on a mutual fund suggestion with people who are in power. He stated, “I guess the really great project for ®™ark would be the one where, and I don’t know if they could ever recover from this [. . .] some people who really are in power to do the kinds of things they do” (2007).

Another aspect of embodiment pertains to the images that are created as part of the press releases for these projects. For some projects, this consists only of images or texts created to describe them. For example, a video clip made to mimic a newscast showed Barbies explaining their situation and images of gloved hands tinkering with G. I. Joes and Barbie dolls, apparently to switch their voice boxes. These images circulated widely on the internet along with various texts describing the project. It is now largely believed that no dolls were ever tampered with despite images that were created to give media consumers a look behind the curtain of the *BLO*’s work. One bit of evidence for this is the absurd latex gloves that the posed G. I. Joe’s surgeon is wearing. They seem to suggest a medical context for the voice box alterations and are therefore humorous when we consider that the surgery is on a plastic doll. The image purports to document an event that never happened to enable an artwork to occur through public engagement. The project’s idea propagated through the media as fact through a series of elaborate press releases that effectively created a public art project. The image was created as evidence for the claim that such a project had been executed. Because there was no final product, however, the images themselves become the artwork.

The status of these images as being evidential and referential complicates attempts to categorize them. In his influential text *God & Golem, Inc.* (1964), Norbert Wiener introduced the concept of operative images. Describing machine reproduction, Wiener distinguished the idea of a pictorial image, as directed at the task of representation, from what he called an *operative image*. Although pictorial images represent the original form, operative images perform the same functions as the original. We may think of examples of operative images from science in regard to things that we can never actually see with our eyes. For example, images of nanoscale phenomena can be thought of as operative images because they depict what scientists believe are the fundamental aspects of what they are studying. This is evidenced by the fact that scientists study these images as data as opposed to using them, as they do in other contexts, for illustration or evidence. These images are operative in the sense that they actually are the work that is done in nanotechnology research.

In the case of the *BLO* project, the G. I. Joe image is central to its power to capture interest. In the G. I. Joe image (see figure 4.2), the function of the original is being carried out by the image. In the absence of the original—that is, an actual altered doll—the image carries out its intended function: to spread an idea about gender and children's technologies. Thus, the image of the G. I. Joe is an operative image: it performs the function of the technology. It makes the viewer aware of an argument that this imaginary toy technology is creating a certain view of gender by contradicting our everyday expectations of what the toy soldier should say.

Interestingly, like a depiction of a unicorn or an ascended saint, the image depicts an original that never existed. This differs from the case of the SmartMom suit, in which the image at most depicts a drawing of the potential suit. By contrast, the *BLO* image appears to be of the object itself. The ®™ark website is the thing itself. It claims to be a corporate website and is, in fact, a website that uses image cues and language like those on business websites. The website itself is the only creation: there is no company behind it as such, so the website is both the evidence and the depiction of the idea.

Although we may never know, for example, whether *BLO* physically tampered with Barbie dolls, this point is less crucial than understanding the range of activities that tactical media artists use to create media coverage. Like all tactical media, the *BLO* project revolves crucially around the media regardless of any objects that are created as a part of the piece. The *BLO* depicts something that seems plausible, and indeed it is the idea of the project that is its power. The potential disappointment that viewers may feel on learning how tactical media works is a complex emotion. It is hard to diagnose whether this feeling is the loss that viewers feel about being duped or disappointment related to a wish that these ideas become material. In any case, these feelings are somewhat inverted in the reactions of many of *BLO*'s peers, who believe that the art is all the more brilliant because it exists as an idea and a material paper trail rather than as the object itself.

There are many applicable science studies theories that explore this type of tactical media project. Latour might find this form of immutable mobile disconcerting, because he does not envision explorers who bring home inaccurate maps to make political points (1987). Yet this is a false testimony, a lying virtual witness (Shapin and Schaffer 1985). Some tactical media images do portray actual objects as they are, so they can be easily confused with other images that act as apparent proof of the construction of a technology that never existed. Instead, these images are calculated to produce an effect in the viewer. It is not photorealism that indicates whether a project is or is not an operative image, but rather the context of the object's deployment that determines what rhetorical strategies (photos, drawings, and logos) would be most likely to convince an audience that something is what it claims to be.

Herein lies one difference between how the tactical media network and the scientific network assess the validity of projects. *BLO*'s project was greeted as a major success among tactical media artists, whereas in science, evidence for building a technology that does not exist is potentially considered not only invalid but also an ethical problem. If a robotics laboratory that is trying to produce a flying robot attaches fishing line to make the robot float to give an idea about how this might be done, the image of the floating robot will not constitute proof of the invention of a new technology once the strings are discovered. This deception is considered fraud, impugning the character and practices of those involved, so that other findings of the involved parties might well be brought into question. This is a departure from industry standards where, for example, concept cars are regularly designed or mocked up without the intention to actually produce the car at scale. In contrast to science or industry norms, *BLO* was heralded all the more for its success in producing a political idea in the minds of viewers by using only images.

THE TECHNICAL IN THE TACTICAL

The use of technical materials and related expertise is an important way for tactical media artists to gain credibility, both in their community and with the public who views their projects. Although some technical skills can be fudged, such as the *BLO*'s images, which did not require artists to actually create dolls that worked to get their point across, many projects do require technical skills, and these skills cover a range of types of expertise. These projects are often designed to comment on the technology with which they are working. For example, Shepard's project shows what a community might do with control of GPS technology: post messages of protest on government buildings or create bird songs in a park. Many engage in important debates in the scientific field that touch on public knowledge, as in *OneTrees*, wherein Jeremijenko is offering an experiment that raises questions about the nature/nurture debate based on her knowledge of botanical cloning for a broad audience of people who either intentionally visit the trees or happen into public spaces where the trees are planted. In contrast to the Blaschka models, the *BLO* image appears to be of the object itself. The ®™ark website was also the thing itself. It claimed to be a corporate website and is, in fact, a website that uses image clues and language like those on business websites but does not actually represent a business. Tactical media practitioners appear to be indifferent to whether an actual representation or only an imaginable object exists.

RHETORICAL PRACTICES

Rhetorical practices are the elements of tactical media projects that are not directly material. STS scholars Pinch and Bjiker's notion of the social construction of technology and the accompanying idea of interpretive flexibility (1984) can help us consider how tactical media practitioners use language to shape viewers' perceptions of their material interventions. Pinch and Bijker show that social meaning and design flexibility are intertwined in every technology. In doing so, they also offer a tool for analysis: though in situ technologies are a combination of rhetorical and material elements, scholars should pursue each of these categories to comprehend the social operations that give rise to a given artifact's design and social meaning as seen in the work of its designers and users.

The difference between material and theoretical resources is not normative but rather a typology to separate two types of important strategies that tactical media artists use. Rhetorical strategies often do involve material aspects. For example, the *BLO* press release descriptions of what viewers are seeing in its clips and images fundamentally shape the way in which those materials work for audiences, but they are not entirely dependent on them. The rhetorical elements give the objects that tactical media artists work with specific meanings. Several common rhetorical strategies that tactical media practitioners employ on specific projects are discussed later along with an analysis of why their users believe them to be useful.

THE ROLE OF HUMOR

From the idea of pigeons wearing air pollution sensor backpacks to the tongue-in-check irony of artists and activists taking up the "corporate shield" that protects profit-making companies, or the ®™ark project *SimCopter*'s sex-object men ironically positioned in the place of the usual sex-object women, a combination of critique and humor is present in practically every tactical media project. The humor hinges on making specific claims for the role of a material object. So in the levity of tactical media projects, we again find the mixing of the rhetorical and the material to produce the artists' desired effects. It is also notable that the pleasure that a viewer takes in the project is, at least in some cases, shared by the tactical media artist. In a revealing moment in their documentary (2003), The Yes Men say that performing identity corrections that involved humor through overstating the position of those that they were impersonating was simply more fun than offering new "correct" directions for institutions to take.

One of the most striking elements of tactical media is how these projects work as insider artifacts while also being palatable as pop news blurbs. A major goal of tactical media is for the projects to be spread through the press, internet communication, or word-of-mouth. This act of transferring the project is complicated, however, because often a great deal of context is necessary to understand the full meaning of a project. The result is a split between types of audiences. The public views and reacts to the primary release of the website, story, or project, whereas a secondary audience views the primary materials and watches the primary audience as part of the artwork.

Without the context of tactical media and the expectation that part of the art takes place in the public's reaction to it, some projects are not immediately interpretable, despite their claims to be reaching out to a broader audience. For example, the ®™ark web page performs as we expect a company website to act—as an advertisement hailing the possibility for profits and benefits from efficiencies made possible by ®™ark. The viewer soon realizes, however, that there is something else beneath the smooth exterior of the page. If you visit the website and the satire is not immediately obvious to you, you are in good company. Like those who believed that they were witnessing a Martian invasion while listening to Orson Welles' radio broadcast of *War of The Worlds* (1938) or audiences quickly flipping past *The Daily Show* or Onion News Network, mistaking these shows for traditional news programming, these artworks are not always obvious from the outset. This nonobviousness is part of their captivating power: giving artists more time to transfer their political points, though the degree of the suspension of disbelief is sometimes a surprise to the artists themselves. To fully appreciate the work of ®™ark or *BLO*, it is necessary to also consider the impact that these projects had in the press and social networks as items about each were circulated.

In becoming part of this secondary audience, I found that most of my informants who were not directly involved with the project did not simply stumble on the site on the web. Instead, their experiences were preceded by suggestions that ®™ark was a tactical media project. Although some interviewees did understand the project right away, every informant I talked to found the website through their social networks, as opposed to online searches linking them to the site. Most found out about the project through friends and colleagues. Some were even introduced to the project as an exemplar in art school. These contexts provided by social connections make sense of the ®™ark page. It is, in fact, this insider knowledge of how to understand the mimicry is necessary to appreciate the dry and intellectual humor that much of the ®™ark site provokes. The hook of this work is the humor and irony that allows an individual to experience this political critique, thereby accessing this social group's mode of communication and way of awarding value. The basic politics of the critique are apparent, but it is the method of the critique that enthralls the audience and promotes a sense of community among tactical media artists.

USING VERSUS CRITIQUING

The way in which tactical media artists talk and write about their projects creates a tension between the use of science and technology in their projects and the critiques of science and technology that these projects engage in. Shepard's *Tactical Sound Garden,* described earlier, is an example. In a 2007 interview, Shepard talked about how he evaluates his projects that involve public participation by using criteria drawn from evaluative practices in science. Shepard was concerned that his projects should "work" in a technical sense. This project also challenged the way in which GPS technologies have been developed and how those technologies might be used differently if placed in the hands of community members.[5]

Evaluative practices force us to consider how the creators and performers of a project know that the project has worked. The failure or success of a tactical media project seems to occur at an epistemic level that is rather different from how scientists determine whether an experiment or technology has worked, but the two settings may share some elements. Moreover, various tactical media projects happen on very different registers with regard to this issue. For example, the standard used to determine that ®™ark was successful had to do with public outreach, whereas the overall success of Singer's *AIR* project was in part dependent on technical success, a criterion that would be more familiar to scientists. Later in the interview, Shepard talked about the disparities in acceptance by others, particularly academic communities, depending on whether the artist chooses or does not choose to use evaluative techniques. He suggested that artists are more interested in why those techniques make a project more acceptable: "Another problem is the borrowing of evaluation. We can measure certain parameters of interaction in these projects. I think artists aren't interested in the acceptance of particular techniques . . . It's more about thinking about the acceptance disparities."

Brooke Singer, cocreator of *AIR*, faced the tension between wanting to make sure that her air sensors offered reliable air pollution readings and wanting to critique the way that such readings are taken in standard scientific practice. This tension between the scientific standard and what she and her colleagues viewed as the best practice came to a head over the issue of sensor movement: "With *AIR* there has been a question about whether the results are scientific [. . .] We are moving these things around and the scientific standard is that they stay in place with these things for a long time and do it over and over and over again and take the average reading . . . but there are things our research does really well, like if a person wants to see it [their air pollution exposure] on their daily commute, then we can start looking at the usefulness for these mobile sensors."*

This issue of evaluation and what counts as participation in scientific discourse remains difficult. To launch a critique of science that scientists will consider valid and that the public will accept as scientific, artists often have to participate in many components of the scientific method (for example, evaluation) themselves. The commitments of artists to using some techniques that are labeled as scientific can undermine their ability to make certain criticisms. This circularity of knowledge and permission to participate in scientific discourse or even present ideas to be taken seriously by the scientific community is certainly nothing new to science studies. Epstein (1996) showed that acquired immunodeficiency syndrome (AIDS) activists had to gain proficiency with medical language to participate in the scientific discussion and thereby influence the scientific process. Like AIDS activists, tactical media artists do not want to become scientists. Tactical media artists do engage and learn from scientists, but generally they attempt to exact change by communicating with lay audiences. This is in contrast to AIDS activists' attempts to change a specific scientific practice, that of clinical drug trial protocols. To participate in the scientific discussion and deploy close critiques, these artists master many scientific protocols so that they become to some extent enrolled in the scientific process themselves.

AGENCY OF TECHNOLOGY

Tactical media artists' belief that by intervening in technology they can change society commits them to two positions: (1) technology shapes

*The exchange is from a 2007 interview with Brook Singers which took place in her Brooklyn, NY studio with the author.

society and (2) the trajectory is not set in stone (even if it is a bit rigid and hard to change). This philosophy plays out differently in different people's work and even among an individual's different projects. For many of these actors, technology is a cultural artifact of society, enabled by any group of individuals who are willing to act. Although this group of actors perceives institutional entities, such as corporations and the military, as able and constantly engaged in attempts to control technologies, they are also at once convinced that if large institutions can have an impact on the way that technologies are read and used, then smaller groups of actors (such as themselves) can also shape technologies and thereby offer new possibilities for society.

Tactical media artists attempt to offer other patterns of technology; they maintain that their projects offer new social meanings that can alter society. An STS scholar might claim that this dual position of insisting on the consequences of technology and also on its malleability forces these artists to live in a fragmented world, one in which they are both determinist and constructivist (Smith and Marx 1994). Yet despite the fact that tactical media artists are aware of both these positions, the contradiction is largely absent in tactical media itself. To these actors there is no conflict. For the artists of tactical media, separating technology and society is all but moot, because technology is treated as material culture that like art can be shaped to perform a variety of roles in society.

To put this in terms of actor-network theory, we can think of the technologies built by tactical media artists as actants. They are activated by the social meanings ascribed to them by the community. Like Callon's scallops, da Costa's pigeons provide both means for and resistance to human projects (Callon 1986; da Costa 2006). This way of framing tactical media is useful because it helps to convey the idea that it is up to artists to activate the social meanings of their actants, but their projects have affordances and resistances that are sometimes predictable and sometimes totally unknown to the artists until the object or project has been put into play. Like failed experiments, there are likely many failed tactical media attempts that simply are not taken up into the media or social circulation.

Like experimental scientists, tactical media artists may have hypotheses for the outcomes of their works, but they can never know for sure what the outcome will be. The concept of trajectory in technological determinism is undermined by the actors' explicit knowledge that they cannot know how their projects will turn out in terms of the assemblage of technical components or in the way in which they will be interpreted. For example, in their documentary, The Yes Men emphasize that they did not know what would happen when they initially engaged in identity correction by posing as WTO figures. They eventually became used to having their outrageous claims all but ignored by audiences and began to wonder exactly how far they could push the envelope without a response. Through repeated action, they are able to make guesses about the potential audience reactions, but they are never able to fully predict how their work will be perceived. Other times the reaction to their pranks is immediate. One Yes Men tactic involved performers apologizing to victims of corporate decisions: in the 2011 Gulf Coast Leadership Summit, a BP executive apologized to those affected by an oil spill and promised reparations, only to be interrupted by an actual BP employee, causing a dispute about which person was the impersonator.

Some tactical media artists contend that it is important for them to believe in the possibilities for their new creations. Jeremijenko identifies projects such as *OneTrees* as an alternative to the mainstream, demonstrating that technologies are not inevitabilities. As she put it, "my projects did not emerge from the corporate imagination, and therefore showed that the mainstream corporate technologies were neither comprehensive, nor inevitable, and perhaps not even desirable."[6]

Alternatively, there is a commitment to the idea that technologies lead to outcomes. That is, after all, precisely the power in reformulating them. As creator of several projects critiquing connections between the biological sciences and the corporate world, Vanouse was familiar with science studies positions on determinism. When I edged toward asking him if there was a belief in the tactical media community that social and technological conditions made a great deal of tactical media work based on websites possible only in the particular moment of expansion of the World Wide Web in the early 1990s, he anticipated my concern: "Not to be technologically determinist, but I think the way they approached setting up that company was possible to do really well at that time . . . at that time, the tools to develop the web were not very expensive."[7]

According to Hine, “Peoples’ beliefs about the internet may have important consequences for the ways people related to the technology and one another through it” (2000, 8). Perhaps Vanouse’s idea that there was a historical moment in which a project like ®™ark could come together can be understood through Hine’s view to mean that potential projects emerged from people’s beliefs about what was possible on the internet at that time. Once closure is reached about the possible uses for a technology like the internet or, in ®™ark’s case, the corporate website, the possibilities for change and subversion become limited (Pinch and Bijker 1984). As Vanouse pointed out, the threshold for appearing to be a corporate website, in terms of the degree of sophistication required for the inclusion of complex video and graphic content, has increased dramatically since the time of ®™ark.

It might be argued that the window during which tactical media artists could plausibly appear to be corporations has largely closed, but the philosophy and practices of do-it-yourself media are now ubiquitous. The tactics of tactical media are now so widespread that they no longer go by that name. Indeed, the World Wide Web and social media networks are filled with individual sources of news produced and framed by netizens. Tactical media practitioner Paul Garrin’s concept of “camcorder activism” has been realized through the commodified smartphone in the hands of billions of citizens. Videos and images produced by nonjournalists are regularly carried on networks previously confined to media professionals. Some aspects of the agency demonstrated by tactical media activists is regularly available to users of Web 2.0. At the same time, tactical media practitioners sought DIY means that would allow them to circumvent involvement with corporations. The publicly available but privately held platforms used today would not satisfy the criteria of the tactical media movement for participatory information exchange.

The methods and politics of tactical media practitioners were both reflective and constitutive of the development of participatory media networks. Historians of the internet with a focus on engagement have increasingly found cause to discuss tactical media in relation to the development of Web 2.0 (Harrison and Barthel 2009; Vinogradova, Melnik, and Shaldenkova 2020). These studies may yet reveal the influence of traditions of art activists on the construction of the internet as we know it.

Although it is difficult to directly correlate the activities of tactical media activists with their influence on the development of the social web in a linear fashion, it is clear that the participatory aspects of their goals and interests have been realized, albeit not by means of their own making. Tactical media practitioners bring not only political ideologies that hail from artistic traditions but also the demonstrative quality of net-based artifacts. These artworks served to both realize and influence the further development of the participatory internet. For our purposes, it should be noted that art and the technoscience of the internet are completely enmeshed in the identity of the tactical media practitioner. Although analysts may attempt to sort out the technical ability and the ideologies of these actors, these actors themselves were not eager to participate in such categorization.

CONCLUSION

Tactical media persists. Its practitioners continue to work on political interventions through technical means. Net art as a genre, which sometimes overlaps with tactical media, has continued to develop. For example, Mary Maggic's 2018-ongoing net art project *Estroworld* uses the affordances of myriad pop-up windows to satirically consider the role that corporations play in selling queerness. Forms of tactical media continue because the movement was not associated with a single technology or confined to the internet. The idea of understanding and utilizing the methods needed to attract attention to issues of interest to its practitioners remains viable, if not as novel as it appeared in the mid-1990s.

In the intervening years, some ideas about how the internet might be revolutionary have changed. This could be seen as a sort of social determinism, in which the kind of change that tactical media artists hope to create is limited by the ways in which people conceive of the possibilities for technologies. It is just as sensible to agree with tactical media artists' belief that technology, like art, is a product of and intertwined with society, rather than a separate potentially determined and determining part of society. STS scholars should consider how often the very points that we might be inclined to make about the nature of technology or the interaction between technology, expertise, and institutional power are present in artwork, implicitly and explicitly. Like science studies, many science-engaged artworks are dependent on the details of science and on a reflexive understanding of science to produce critiques. In "Silence in Context" (1999), Michael Lynch wrote about a concept called "ethnomethodological ground zero," an imagined place where nothing is left of ethnomethodology's methods precisely because they originate from other sources. Instead of a set of methods or a central theory, Lynch proposed that ethnomethodologists share an "attitude" of "indifference" (1999), an idea which was surely influenced by Harold Garfinkel's methods (1964).

Similarly, much STS scholarship does not set out to value the actions of others or offer policy recommendations on how a matter might be improved or worsened. Although not always the case, tactical media artists are in general concerned with such outcomes. The very point of their projects is to forward a political agenda. The particulars of the project are part of the vehicle for carrying those agendas forward by making them attractive to media outlets. They are designed to encourage attention and audience discussion about related issues. What is at stake in a tactical media project is, of course, dependent on what the project is and who is involved. Because many tactical media projects involve group work, the motivations and intentions of a project may be obscured—if they were ever clear to any one artist in the first place. The blurring of art and science is often not the point but a side effect of the political agendas of the artists. Tactical media artists are conscious of the rhetorical power of the concepts of art and science. In their practice, they use this knowledge to reshape and recast projects as artistic or scientific, depending on their needs. On this point Jeremijenko was clear: "I avoid the term [artist], except when it is tactical."

In Gieryn's (1983) account, scientists attempt to build a barrier between other ways of knowing and the scientific way of knowing. Tactical media artists pull that barrier down by conducting research and creating projects that contain elements of both science and art, but this is only a side effect of pursuing their political works rather than a goal. Tactical media projects such as *Feral Robotic Dogs* violate the supposed differences between these two communities by using each community's labeling system to gain project acceptance. Jeremijenko's comment evinces a concern for leveraging the language of art and science for a purpose. Rather than repositioning and recalibrating objects so that they can be useful in different ways to different communities, as in the case of the Blaschka models or Berenice Abbott's photographs, Jeremijenko built objects for her own goals and then employed language to emphasize their affordances.

This sentiment was clarified further in an interview with Igor Vamos, one of the founders of ®™ark:

HR: Does it matter to you whether people see this project as politics or art or technological . . . ?

IV: No, whatever it takes for them to listen to the stories.

Vamos's attitude toward my list of potential labels for this work was indifference.[8] What mattered to him was conveying a narrative to encourage people to listen. The format, tactical media, may be incidental as related to Vamos's career as an academic and "emerging media" artist to the particulars of his political messages. Like academics collecting papers to create viable careers, academic artists must maintain connections in the art world and produce artworks relevant to the interests of their affiliated departments. In tactical media worlds, words like *art*, *science*, *technological*, and *political* have explicitly become rhetorical devices for furthering artists' agendas.

5

SYMBIOTICA: CULTURING ART AND SCIENCE

"Science can hide behind the things it is doing for us when it uses living [materials] . . . but this art [we are making] is not commercial. It's not for solving problems [. . .] I want to make art that makes me uncomfortable."
Oron Catts, 2007

In the kitchen is a large glass jar, which must have held some indeterminate foodstuffs in another life. Inside is a tiny chair warped by what must have been a fungus. "Was it made of bread?" I ask. Oron Catts takes the jar down and sets it on his suburban Perth countertop. This was from the early living work, he says. This experiment would have been run at the very beginning of the artist's foray into the life sciences. In his design school days, Catts had proposed living surfaces for furniture, so a living chair makes sense. I smile at the thought that this pioneering piece of bioart history now lives on top of a refrigerator. In the world of bioart, living art takes on a whole new meaning. This kind of domesticity and accessibility is crucial to the way in which SymbioticA artists approach making life crucial to their artwork: by convincing viewers that everyone is implicated in the constant movement between the living and the nonliving.

A community of contemporary activists called *bioartists* addressed concerns shared in the STS community, including corporate development and control of scientific knowledge, privacy issues, futurism in science, particular biomedical research, hype around genetics, and the human genome project. Bioartists address these concerns through a variety of means, including material use of scientific equipment and reach protocols; high art installations and public art displays, which are often held in nontraditional locations; and publications in art venues, academic journals, and the popular press. This movement is of interest to STS scholars both because of our shared concerns and because of the network of technical skills and knowledge sharing that bioartists are creating.

This chapter is based on my ethnographic study of SymbioticA, a laboratory for the biological arts that initially created projects such as *Fish and Chips/MEART* (2001) designed to generate both science and art outputs but that grew to focus on the latter as the group gained resources and technical skills. I went to SymbioticA for extended visits twice, including once for an intense six-month period as a resident, where I followed other residents, researchers, and others around the lab, gallery, bioart courses, lab safety protocol information sessions, public and small group meetings, and a multiday animal care training, and I conducted extensive interviews. I have since followed the careers of residents and researchers through follow-up interviews, visits to public art and gallery space, and visits to other informal and formal laboratory spaces. Using these experiences, I argue that some artists who work with biological materials are situating themselves in both art and science worlds and making use of resources and interpretations available to them by attempting to create works that fulfill criteria from both knowledge communities. In other cases, artists working with the same materials behave very much like STS scholars working through material means; their goals are to launch critiques about cultural, political, and technical issues that they observe in the life sciences.

SITUATING SYMBIOTICA AND DEFINING THE DIMENSIONS OF BIOART

Over time, SymbioticA has become a central node in an international network providing expertise and lab space to visiting artists and bringing international artists into conversation and collaboration with University of Western Australia (UWA) scientists and Perth-based artists. Subjects have stretched beyond tissue culture into new areas including environmental science and sleep research. Scientists remain important but are no longer vital to the creation of these artistic critiques of biotechnology. Bioartists have seen themselves not as the mediators of scientific knowledge to the public but as the producers themselves. Their material assemblages and rhetorical performance illuminate, contextualize, and critique the life sciences rather than celebrating or didactically explaining biological subjects.

The term *bioart* is a contested category that is used colloquially to refer to virtually any art that engages with contemporary biology, yet artists in the field continue to insist on specific meanings, which they both identify with and reject (Britton and Collins 2003; Munster 2006; Kac 2006; da Costa and Philip 2008; Mitchell 2010; Hauser 2016). Coined by Eduardo Kac as a referring to his 1997 artwork *Time Capsule*, which involved the implanting of an identification microchip into his leg (Britton and Collins 2003), bioart quickly became an art term used by curators to describe any piece with living components. Even as this chapter explores bioart, it is important to note that Oron Catts and Ionat Zurr of Tissue Culture and Art/SymbioticA question this term as they do not describe their work as being about art and science but rather as about art and life. Among their concerns about the term bioart are a set of tensions around artists or scientists doing one another's work. Catts has repeatedly noted in my interviews with him and in public contexts, like his recent discussion of the *Crossing Kingdoms** project as part of the *Art's Work in the Age of Biotechnology: Critical Methods for Collective Experiments* exhibition for the University of Pittsburgh (2021) that "the importance of having artists in the laboratory is to engage with the same practices with a different point of view."† Catts has also expressed the same idea by saying that

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* *Crossing Kingdoms* was a 2018 project created by Ionat Zurr, Oron Catts, Tarsh Bates, Elise Cachat, Jane Calvert, Alistair Elfick, Susan Rosser & Erika Szymanski. This interdisciplinary collaboration between artists (SymbioticA, University of Western Australia), scientists and social scientists (SynthSys, University of Edinburgh) proposed to create yeast-mammalian cell fusions, while exploring such questions through art. For more from a social science perspective on this project see Szymanski, E., Bates, T., Cachat, E., Calvert, J., Catts, O., & Nelson, L. et al. (2020). Crossing Kingdoms: How Can Art Open Up New Ways of Thinking About Science?. *Frontiers In Bioengineering and Biotechnology*, 8. https://doi.org/10.3389/fbioe.2020.0071.

† These remarks were made by Oron Catts as part of a panel discussion for the artwork *Crossing Kingdoms* which was held as part of the *Art's Work in the Age of Biotechnology: Critical Methods for Collective Experiments* for the University of Pittsburgh on April 2, 2021n.

"when artists do science, it is often bad science and that when scientists do art it is often bad art," which points toward his idea that merging art and science is not the right approach (thus his concerns about the term bioart). Yet as Catts points out, the moments where the content interests of artists and scientists relate are points of interest and excitement for the artists. In discussing their project *Crossing Kingdoms*, Catts speaks of how some synthetic biologists are proposing and doing what artists have been thought since the 20th century to do for society, and that is "making strange" by creating "life forms that exist outside of any type of cultural or scientific specifications."

In an art world captivated by theory, where almost every work engages both scientific and artistic themes, it may not be surprising that the categories in which artists place themselves and their works are minced into microdistinctions. Bioartists are partly defined by their concentration on critiques of science and scientific power. Definitions of bioart range from the very general (anything displayed as art that combines biology and art, such as photographs of cells) to a narrow concept that specifies a set of practices, which includes using biotechnological techniques to critique modern biology. An example of the latter is the *Tissue Culture & Art (TC&A) Project's Disembodied Cuisine* (2003), in which cultured frog tissue is presented as meat as a way to critique the idea of using tissue culture as a technique for creating meat without killing animals. This is because fetal calf serum is necessary to create the culture medium required to feed the cells that grow into what is referred to as *in vitro meat*. This serum requires the deaths of fetal calves. *Disembodied Cuisine* was begun in 2001 and exhibited in 2003 in Nantes at *L'art biotec,* curated by Jens Hauser. As Driessen and Korthals (2012) noted, designs disclose moral worlds and, in the case of in vitro meat, discontent with the ethics of agricultural systems. TC&A is further noting a discontent with the ethics of laboratories being implicated in rendering ethically "clean" tissue cultures.[1]

As evidenced by these distinctions, the tradition of dividing art into schools and movements gives ample incentive for actors to engage in self classification. The formation of art factions is part of the process of self-fashioning, of becoming an artist, and it is through these factions that credit is often awarded. Accordingly, these actors are trying to orient themselves in relation to other art movements and to designate different types of art practices and orientations, but there are other influences as well, including scientific communities and a concern for the political impact of bioart. Bioart and tactical media are social movements. Although bioart is frequently on display in art museums, significant challenges for mounting such exhibitions remain. The need for and usefulness of such regulations may be questioned by bioartists and curators; significant barriers exist in the areas of health and safety and in providing the care that living things require in a gallery setting. Bioartists themselves appear to be uninterested in modifying their production to suit the established parts of the art network and see it as vital that living work be shown rather than the easier-to-curate documentation of bioart. The struggle over how to define bioart involves not only choices about self-description but also the formation of networks of people and materials to support projects and decisions about where to show artwork and where to seek funding.

There is considerable border policing of bioartists in regard to valuing projects that use biotechnology materials for the purpose of critiquing current developments and foreseeable uses of biological science. This policing behavior is on display in their attitude toward art shows and reviews that display science-related work that is not critical alongside critical works. Bioartists talk about such exhibitions as sources of confusion for audiences about the point of their work, and they tend to distance themselves from science artworks intended to communicate science rather than provoke new ideas or experiences. For these bioartists, public engagement means endowing viewers with a critical eye as well as access to the skills and materials required for entering scientific discourse, at least at an amateur level, rather than attempting to communicate the value of scientific findings and the possibilities for science-improved futures to the public. Here, the bioartists' way of thinking seems to correspond to Collins and Evans' (2002) category of *interactional expertise*, the ability to understand expert knowledge well enough to talk about it in an informed way. Bioartists extend the boundaries of interactional expertise, because presenting technical skill and familiarity with science practices is often crucial to acceptance by scientists, who offer resource access. For many in this artistic bioart identity depends in part on knowledge of technical systems. At the same time, there are practicing bioartists who direct their skills to particular projects and acquire only the expertise necessary for their artwork. To some degree this mirrors how interactional expertise works among STS researchers, who do not have comprehensive training in the scientific or technical area. STS researchers, however, gain the expertise necessary to converse about or work on an individual project.

Attempts to understand the relationship between art and science are plagued by constant redefinition. What counts as art or science varies according to the particular person, the place, the time, and the specific tools and set of concerns regarding the object. Moving past the idea that context counts and determines how art and science are labeled, this study focuses on the ways in which actors shape those categories. Through interviews and the examination of specific projects, this study seeks to understand how actors shape their work and their own identities. The communities of knowledge production involved in art and science are not stagnant structures or groups of identifying facts used to locate types of knowledge. Instead these communities of actors who are shaping every aspect of their work are constantly refining their definitions of what counts as part of their practices, the methods by which inclusion is identified, and the designated knowledge they recognize. For art and science scholars, this emergent set of practices and people provides an opportunity to think about how rhetoric and material strategies bolster claims of participation in art or science communities. Bioartists represent a particular version of art-science relations, which is interesting both because it complicates public ideas about science and because it does so in a way that is novel: through material means. Bioart is a compelling example because it complicates easy ideas about the relationship between art and science by offering a case in which artists are engaged in a direct critique of science using its own materials and techniques.

Contemporary scholars of science and technology place considerable weight on the role of nonscientists in knowledge production and scientific debates, often with an eye to the role of citizen scientists (Wynne 1992; Rogers 2011). By contrast, this study offers a look at a different kind of expert, one who is also working with questions about the role of technology and science in society: the artist. These art-based inquiries have, in many cases, yielded concerns that are markedly similar to those in science and technology studies. For example, artworks such as *Relative Velocity Inscription Device* (2002) engaged the issues of genetics and race, similar to those discussed by Jenny Reardon (2004), and *Latent Figure Protocol* (*LFP*) (2007–2009) by Michael Lynch, Simon Cole, Ruth McNally, and Kathleen Jordan (2008) was related to concerns with DNA fingerprinting and accuracy. Many of the artists who produce such works style themselves specifically as interventionists, and their acquisition of jargon, technical expertise, and scientific knowledge in service of a political agenda resembles the actors in Steve Epstein's canonical study of AIDS activists (1996).

Artists such as Vanouse and Jeremijenko made use of STS theories and texts in their artworks. This is likely because their influences as artists in academic settings are not limited to the sciences: Catts and Zurr, da Costa, Kurtz, Bolen, Lovink and Garcia, and many more worked in university research contexts. Hence, the academic context offers not only technical resources, expertise, and potentially funding from the sciences but also specialized knowledge from other disciplines. These art communities seek entry to scientific debates and controversies through technical skills and knowledge of the social processes that are crucial to science. This overlap in issues of concern is an opportunity to think about the similarities and differences in the ways in which scholars and artists engage subjects of interest within and across their respective fields, and how each group translates these issues to the public. It is also worth noting that although STS scholars may be less than familiar with their work, these actors were generally aware of the concepts of science studies. My background in science studies frequently opened doors to conversations with SymbioticA researchers, and some artists expressed interest in learning about my work and science studies more generally, and in using it in their own work.

SYMBIOTICA

I shut the metal door quietly behind me. There are lots of shared spaces at UWA's School of Human Sciences. I am between interviews with scientists and administrators, who share lab resources and a building with an unusual group of researchers: artists who were trained as designers whose work questions the biological sciences. See figure 5.1 for an image of the

SymbioticA laboratory space. More than one interviewee has mentioned "the prize." In 2007, SymbioticA won the Golden Nica (the highest Prix Ars Electronica award) in a newly established ("inaugural") category called *Hybrid Art*. The award held importance for how SymbioticA was viewed both internally and externally.

The scientists I interviewed described the group mostly in terms of their lab bench needs and the occasions on which they gave the artists excess materials (usually tissue or blood cultures). This utility and the scientists' belief that whatever the artists are up to, they seem to take good care of the lab space, seem to be creating a symmetry that the scientists can work with. As one researcher put it: "they [the artists] are just another lab group."

SymbioticA is a collection of experts and equipment with stable access to institutional passage points, such as ethics review boards and funding. UWA is a major research institution, and myriad people circulate throughout it, bringing their own ideas and techniques and participating in structured activities such as weekly meetings and laboratory protocol training. Founded in 2000 as the first artistic research laboratory of its kind, SymbioticA has served as a model for other similar ventures. In the same period, other artist-science collaborative institutions have also formed, including the Swiss Institute's Artists in Labs (AIL), led by Jill Scott in Zurich, Switzerland, and the privately funded Le Laboratoire in Paris, France. SymbioticA is unique, however, in functioning as a wet biology lab in a research university.

SymbioticA originated from the work of Ionat Zurr and Oron Catts known as TC&A. Miranda Grounds, a cell biologist at UWA, took an interest in the vision that these artists promoted and helped them gain access to biological laboratories and scientific expertise. SymbioticA was formally founded by Grounds, UWA neurologist Stuart Bunt, and Oron Catts. It has grown from a space in the school in which the founding artists could pursue their biotechnical projects to a facility that encompasses the founding artist's practice, including TC&A and SymbioticA research activities, teaching graduate and undergraduate courses, supporting visiting artists (known at SymbioticA as residents), sponsoring arts programs, and hosting meetings between scientists and artists. The first year of SymbioticA, Catts and Zurr were in residence at the Tissue Engineering and

Organ Fabrication Laboratory at Harvard Medical School. Although Catts directs the program, contrasting visions of the potential of SymbioticA have always been in play: perhaps it is this contestation that has made SymbioticA such a productive interdisciplinary place.

In contrast to the more technical space envisioned by cofounders Oron Catts and Stuart Bunt, SymbioticA cofounder Miranda Grounds' original vision of SymbioticA was that of an "art and science" atelier. The resources were designed around a multipurpose space where artists (dancers, painters, and performing artists) could interact with scientists. This commitment was somewhat at odds with Catt's sense that the artists must avoid representing science and instead make their own work, though he saw ways in which the resources might be aligned to accomplish his goals. Its physical spaces include a top-floor studio located in the human sciences building that is a space for artists. Its design reveals preconceptions about what kinds of work that artists working with scientific materials would be doing. The initial design emphasized the excellent natural light that the ceiling windows provided, but the room did not contain the tissue culture equipment that SymbioticA needed. The artists have converted the studio to office and meeting space and borrowed lab space elsewhere in the building. As of 2009, SymbioticA had one lab entirely to itself and several shared lab spaces, including shared space in the animal research facility and in the spectroscopy laboratory. The practice of sharing space is typical of all of the research groups at the School of Human Sciences.

The membership of the groups that work on formal and informal bioart projects is frequently in flux. During its more than twenty-year history, SymbioticA has hosted more than sixty full-time resident researchers. They have ranged from well-known artists who had already worked with biological materials, such as Paul Vanouse, Stelarc, Steve Kurtz, Paul Thomas, ORLAN, and Adam Zaretsky, to fledgling students new to working with scientific materials. Residents and researchers work in UWA's laboratory spaces and in what SymbioticA director Oron Catts calls "a halfway house," an art space housed in the School of Human Sciences building. SymbioticA researchers may work in concert with one another or on their own solo projects. In addition, SymbioticA offers researchers access to a wet laboratory space (see figure 5.1a and 5.1b for images of the two main types of space at SymbioticA).

5.1 SymbioticA laboratory space/headquarters, School of Human Sciences, the University of Western Australia. *Source:* Photograph by Chris Cobilis, 2019.

Even as these practitioners endeavor to create a stable institution for their work, in the tradition of subverting labels as a technique for producing an original art movement, Catts and Zurr reject the term *bioart*. Instead, they professed to “maintain the integrity of the disciplines,” a potentially risky position for artists located in the School of Human Sciences. These actors see themselves as artists practicing in the sciences rather than as hybrid artist-scientists, identifying their work as *biological arts*, a rather fine distinction.

During my fieldwork at SymbioticA, I had the opportunity to interview scientists, artists, university administrators, arts managers, ethicists, animal welfare and biosafety advocates, curators, and graduate students associated with SymbioticA and other comparable labs. I also observed and talked with undergraduate students taking courses at SymbioticA. In addition, I examined a variety of textual materials, including science publications, lab notebooks, tissue culture protocols, artists’ statements, funding documents, media coverage, artist blog culture, artist and art institution documentation, curatorial calls for artwork, statements and advertisements, and gallery documents.

I was able to interview several other residents and former residents who were in the process of leaving SymbioticA when I arrived or had completed projects in the past, and this gave me a sense of how these artists reflected on their residencies. I was a regular participant in meetings, including the weekly presentation/discussion series, which functions very much like a lab meeting. I also attended a workshop for introducing new artists to the work of biological art. Toward the beginning of my stay in Perth, I attended a multiday animal ethics course. This was a site of mixing between new or young scientists and students and residents of SymbioticA. I was also able to view several art shows, openings, and gallery displays. In nearly every case, artists and scientists were open and eager to talk with me about their work. SymbioticA, like many groups of contemporary artists, functions in a profoundly cooperative way. Most SymbioticA projects are collaborative affairs that include not only a combination of artists and technicians or scientists but also often several people from each of these categories. In this sense, projects at SymbioticA have more in common with the collaborative work that we observe in scientific research groups than with the imagined realm of the lonely genius artist. I was able to act as a participant-observer in traditional tissue culture work, including growing tissues over polymers.

SKILLING

"Are we going to use the DIY hoods?" I ask Catts. There are half a dozen homemade hoods scattered on tables in a biology lab at Royal Melbourne Institute of Technology (RMIT) created for a SymbioticA-led event called Biotech Art Workshop (November 2009), held in conjunction with the *Superhuman: Revolution of the Species* exhibit at RMIT Galleries. One hood seals with plastic wrap, whereas another unfolds like a pup tent. Catts grins and remarks that he is unconvinced that these hoods would actually work. Even the best of them seem dubious, even to me, the airflow looking more like a simulation of a scientific sterile hood than something that could be reasonably operated by a beginner.

In fact, this standard of what would count as a "working" hood does not seem to be the point at all. We might think, then, that the real purpose of this introductory workshop was not to teach actual DIY skills to create a sterile hood but instead to symbolize and simulate a laboratory environment for direct participation. By performing the performance of the laboratory and understanding the basic requirements and steps for DIY biology, the workshop familiarized participants with general protocols but primarily focused on ideas about accessibility and an understanding of the social, political, and cultural issues at play, areas which are after all, the milieu of many contemporary artists. Participants were also given a chance to learn jargon and basic etiquette of the laboratory, which STS scholars have shown, in theorizing the concept of interactional expertise, can be crucial in gaining future access to the lab (Collins and Evans 2002). For similar reasons, biological artists seem to have come to some of the same conclusions as STS scholars who work in labs: initiation into lab cultures involves technical knowledge but also linguistic knowledge. In addition, finding a way to show others in the community that you have additional skills to contribute to scientific conversations, potentially from disciplines outside the area that you are attempting to enter, can be very helpful in creating and maintaining relationship with scientists. In fact, Catts pointed out that it would take many visits to the lab before students could be involved in work that involves tissue culture and biological arts, so perhaps this workshop is more properly compared not to scientific lab work but to scientific pedagogical processes.

For Catts, these visits would encourage sustained relationships between the scientists and the learning artists. It seems that the biological arts community as a social movement includes a rhetorical appeal to accessible science, an appeal that does not, however, include acquiring the necessary skills to do science. Catts looks knowingly at me and walks past the participants' handiwork toward the corporate hood, where he is intending to demonstrate a tissue culture technique with meat from a supermarket. Working does not seem to be the point; the workshop functions primarily as participatory activity. Catts's way of thinking about motivating people to become involved in biotechnology does not differentiate between representations and contributions, and it conforms to earlier STS ideas presented by Pinch and Bijker on the role of experiments and demonstrations. Hacking (1983) showed that interventions implicate an external entity realism. To paraphrase Catts' efforts, if you can culture them, they are real.

My question and implicit critique (that the hoods we had made would not be usable) was out of context. The purpose of the hood was not related to the sense that bioartists were making of involving participants in thinking about their access to science and its representational modes. The hoods were instead meant to evoke lab aesthetics, rather than "working" in the conventional functional sense in a scientific laboratory. That is not to say that bioartists are not deeply concerned with questions of working. Rather, their sense of when it counts for a piece to be living and when the idea of it being living is enough intersects with the constraints of galleries and health and safety committees. Or, as in this case, the desire to get participants thinking about the materiality associated with supporting what the artists would call the *semiliving*. Fragmented bodies that continue the basic processes of cellular life are a reminder of the divisibleness of life in tension with the technical system needed to sustain even a few cells outside the body.

This fact outweighs the need to create functional DIY sterile environments. Though they are using similar tools to those of scientists, and many pedagogical labs do not lead to usable scientific outcomes, the artists are prioritizing an interest in representing laboratory practices over creating working tools. This is rather different from the artists' central concern for their own artworks—to display living work in a gallery—yet it aligns with scientific outreach aimed at creating public interest in, for example, STEM (Science, Technology, Engineering, and Math) through displays that do not necessarily need to hold up to scientific research standards. The DIY bio movement and training workshops allowed artists who did not have access to institutional contexts for technical training to acquire knowledge of simple biological lab techniques. Many SymbioticA residents, for example, Canadian artist Tagny Duff, undertook DIY bio projects before coming to SymbioticA or gaining other institutional connections. In some cases, SymbioticA residents had already built or would go on to build such resources for other users, including Paul Vanouse's Coalesce BioArt Lab at the University at Buffalo in New York, Jennifer Willet's INCUBATOR art lab at the University of Windsor (Canada), and Kathy High's BioArt Initiative at Rensselaer Polytechnic Institute. The processes necessary to gain access to big science and its large-scale tools in the contemporary period are complex. Some such tools are out of reach for independent artists who turn to DIY as a solution for their interests, which ultimately carries an outsider politics and sometimes an outsider aesthetic. At the same time, many find other ways to access the tools and techniques that interest them through creating new resource platforms or accessing materials and skills in unexpected ways. This parallels the argument in "Between a Bach and a Bard Place, " in which Douglas Kahn describes the San Francisco Bay area scene in the late 1970s. At that time, computer musicians at Mills College began learning computer programming for the first microcomputers because they had no access to the big science computers at Stanford's Center for Computer Research in Music and Acoustics. Perhaps it is worth noting that this process is also encountered in other cases of limited access, when scientists themselves attempt to gain new skills in the absence of technical equipment.

Identity as an artist or as a scientist is also at issue in how these artists and collaborating scientists obtained the skills to create their bioart projects. Technical skill acquisition is typically made in person through university lab settings, though workshops and how-to documents abound. SymbioticA cofounding artist/designers Zurr and Catts were educated in the storied laboratory of Charles Vacanti (home of the "mouse-ear") for a year before returning to produce artworks at SymbioticA. Owing to Australia's strict regulations on the movement of living materials (both in and out of the country as well as across state lines), displays of their artwork must often be created on-site. This is sometimes done through local universities and other research institutions or by purchasing local materials that are either easily put together or can be put together in specially created laboratories inside the museum. In either case, technical skill is required.

The politics of these artists involve an advocacy of the democratization of science. They are committed to a do-it-yourself view of science and tissue culture, and to attempting to transfer those skills in workshops. Their motives probably stem from the artists' early experience with at-home experimentation. In the United States, trends toward DIY, particularly synthetic biology and its relationship to amateur work, initially raised the hackles of many conservatives, as well as the interest of the FBI and homeland security (Pollack 2010; Saletan 2011; Vaage 2016; Roosth 2017). Instructive here is the infamous case of Steve Kurtz, explored in Chapter 4, an artist subjected to legal action over the course of several years because he used biological agents in his artwork on GMOs for the Massachusetts Museum of Contemporary Art Strange Culture 2007).

To be sure, there are problems with the claim for DIY skilling. Major bioart projects were not created in basement laboratories. The original artists had excellent training and resources before they ever exhibited their first work, and they have been able to pass on, both tacitly and through written protocols, the knowledge and skills that it takes to have what Zurr (2009) referred to as “feeling for tissue culture.”[2] The tensions between the pedagogy and critical politics of DIY bioart were on display in a workshop held in Melbourne in November 2009. Catts and SymbioticA laboratory manager Greg Cozens taught participants to make do-it-yourself sterile hoods. Later, students were directed to use the hoods in the teaching laboratory. Yet after the hoods were assembled and reviewed by the workshop leaders, they were set aside.

The fact that in this instance artist politics did not live up to the claim that everyone can be involved with technical practice might simply be an artifact of this one-week workshop. Surely it was intended as a thought experiment, however, provoking the conditions of engagement by suggesting that anyone (even an artist) can know, contribute to, and critique scientific knowledge. At the same time that participants were encouraged to think about their ability to access scientific techniques, a critique was implicit: science is usually locked away in laboratories, so this opportunity to try out citizen science contains the message that science should be accessible, though it often is not.

For some bioartists, this is an important point of contention. Catts frequently expressed his disdain for what he termed *white goods*, commercial lab equipment that separates users from processes. A major focus of STS research (Latour 1999; Pinch and Bijker 1984), the black-boxing of technologies, is problematic for Catts owing to the distance it creates from the life that is being manipulated. He complained that scientists and technicians do not need to know how the equipment works for data to be taken and therefore may remain ignorant of the interworking of technologies on which their research depends.

Catts grimaced as he pointed to the tiger logo on the highly stylized RMIT lab incinerator. To him, bioreactors reminded him of computer processors, and he did not care for biology equipment that he believed gave the user a sense of clean, easy work. Catts connected this to the metaphor of genetic code. Biotech companies depicted computer-like biological machines as being able to process life forms into data through mapping life as code, a conceptualization that Catts contended paralleled some scientists' own ideas about being able to black-box certain types of information. Such machines starkly contrasted to Catts' own utilitarian tools made to meet the specific needs of projects, usually as cheaply as possible, and often gleaned from other projects and reused in new ways. Catts' dislike of corporate scientific equipment probably flows from his training as a designer and his attention to the other resonances besides function that an object may offer a user. With this in mind, it is somewhat easier to see what is at stake for SymbioticA when it trains new bioartists. Ultimately, however, it is difficult to know what we should make of hoods that are nonfunctioning idealized representations of access to tissue culture techniques for nonscientist amateurs and artists (Rogers 2011).

USING VERSUS CRITIQUING

The Contemporary Photography and Visual Art Center in Buffalo's revitalized downtown is holding its fall opening. The first piece that the visitor encounters is *Latent Figure Protocol* (2008), the work of Paul Vanouse, a SymbioticA alumnus. Four projections create a visual gathering of the documentation of the final images from the artist's "reversal" of DNA fingerprinting technology: a copyright symbol, 01, ID, and a skull and crossbones. Each final image represents a painstaking process of learning the lengths that a particular enzyme cuts out of a particular piece of DNA and arranging those lengths to create a specific image. If visitors encounter only the images, they will surely be affected by the artist's suggestions about the nature of this supposedly objective process. It may not be readily apparent, however, that a complex technical process has been used to produce the image (as opposed to a manual or image-editing process). The projected figures are themselves impressive. Yet the performance of the work, in which Vanouse explains his motives and his concerns about proprietary enzymes used to cut DNA strands at specific points, such that the images for a known strand of DNA would be different in different labs (significantly complicating comparison), means that it is not simply a matter of transforming an image. Rather, the work represents the transformation of a biotechnical process for the purpose of art and a specific political message. In effect, Vanouse's art both relies on and criticizes the wet biological processes involved in DNA imaging.

Paul Vanouse has created a variety of projects that range from tactical media to bioart, a mixture of art and biology. His *LFP* reflects concerns about public understanding of the meaning and validity of DNA fingerprinting. This pun on latent fingerprints suggests that Vanouse's work reveals something previously hidden about DNA fingerprinting and its uses. Here, genetic material is placed into gel electrophoresis trays that are fitted with cameras to show the gels on the walls of the gallery, as samples being run in the gel electrophoresis trays. When completed, the tray produces a pictorial image: of a copyright symbol, a skull and crossbones, and a zero or a one. Vanouse often adds variety and bolsters his case for the complications of this technique by showing videos taken at earlier times of the gels running to produce images other than the live one in the gallery. As well as showing the images and the gels that created them, Vanouse gives a lecture-style performance to gallery goers in which he describes his technique. Proteins move along the gel based on their size. The various sizes are achieved through cutting the DNA in specific places. These places are determined by *restriction enzymes,* specific enzymes that are used to do the cutting. Vanouse explains that he has written a computer program that uses the fact that different enzymes cut the DNA to different lengths, allowing him to organize the enzymes to produce any picture that he designs. He uses this technique to critique DNA fingerprinting technology and suggests that although the name sounds as if it provides solid information, the technique is more subjective than most people think. These public interactions create a place for viewer feedback and discussion. As Vanouse puts it in the technical description of the project on his website: "The *LFP* imaging process relies upon knowing what size DNA fragment is required for each band to move at the proper speed to make the correct image. *This is essentially doing molecular biology in reverse* [emphasis mine]. Usually, scientists use imaging techniques to determine an organism's genetic sequence, whereas *LFP* utilizes known sequences in online databases to produce "planned" images" (Vanouse 2007).

The images that Vanouse chooses are meant to provoke questions about the way in which our culture understands the meaning and uses of DNA fingerprinting technology. The piece required Vanouse to be intimately familiar with the technical aspects of gel electrophoresis, to the point that he was able to tamper with it to design this project. He further inflects new meanings for the device in the public sphere and displays the gels themselves in personal exhibitions and as projections on the gallery walls. This allows them to be seen and inspected easily by audiences, unlike their scientific counterparts, which are usually tucked away in lab spaces. Vanouse projects the gels onto the wall during the display as well as prerecorded gels that make other symbols. The piece calls into question not only what we know about DNA fingerprinting technology but also how much we can trust other opaque biotechnologies. It also signaled a shift in which some artists who were working with tactical media began to move further toward biological concerns. Although it is impossible to speculate about the reasons for the move toward bioart, a subject that is examined in detail in the coming chapter, it is clear that tactical media artists targeted what they saw as the power of corporations in the digital space. As new genomic sciences took center stage in the early 2000s, some of these actors turned their attention to the rising field of genetics, tissue culture, and biotechnology.

The complications of both using and critiquing science occur across a broad spectrum of art-science collaborations. For SymbioticA artists, in this case TC&A, a tension exists between using and critiquing science; a parallel tension exists between serving and critiquing science. In their conflict with the Wellcome Trust over the *The Pig Wings Project* (2005), there was a controversy about who would represent science, in this case, in the form of the Human Genome Project (Zurr and Catts 2005). The UK-based Wellcome Trust was among the foremost funding bodies supporting the complete sequencing of the human genome through the Sanger Institute. This was completed in 2003, two years ahead of schedule owing in part to the additional support. The Wellcome trust initially committed to sequencing one sixth of the human genome in collaboration with the international scientific consortium that made up the Human Genome Project, but it increased its investment to decorate one third of the genome. The result was that the Wellcome Trust's Sanger Institute was the largest sequencing contributor to the project. In addition, the Wellcome Trust was and remains an important supporter of interdisciplinary arts in the area of health and biology. It was in this context that SymbioticA artists believed that their role as artists involved a right or even a duty to critique the powerful, in this case, science, and the Wellcome Trust's involvement in it.

It is unusual that the artists' work was not included after they had been invited to submit. It is entirely possible that the curators themselves had other ideas about why the artwork should not be included. By the artists' account, the Wellcome Trust contended that the scientists whom it funds engage directly in the production of scientific knowledge, whereas the artists that it planned to contract were welcome only if they reproduced what the organization believed *a priori* to be public opinion of the genome project. Put more coarsely, as the artists saw it, the gallery wanted artists to advertise the value of the genome, whether they saw it as positive or negative. The Wellcome Trust gallery could not imagine a position that couched the genome project in anything other than the most portentous terms. They believed that they understood genome science and even what the public would potentially think of it. At the same time, they believed that it would be valuable to use the voices and artworks of artists to critique the private sector's intentions to patent genes.

Jeremijenko explicitly made the point: "What is it that the artists have that these corporate interests are interested in? It is not the art; it is the access to the public imagination" (2000). Such access is at stake in many interactions between scientists and artists. Jeremijenko suggested that the way in which people direct attention to art is desirable to scientists and science institutions; therefore they will continue to pursue artists for their role as perceived conveyers of relevant scientific information and creators of attitudes and imagined possibilities for science and technology. In this model, the artist always has a duty in the role of artist to produce work critical of power. For bioartists, that power has been identified as science. In this case, the artist is under siege by powerful institutions to produce work that they perceive to be in the service of either public information or engagement.

The Pig Wings Project was about defying expectations. An audience anticipating a pig with wings was instead presented with tiny, cultured tissues. Anticipating a celebration of the Human Genome Project, the Wellcome Trust was confronted with work that questioned how artists are used for science-related public relations. The story of *The Pig Wings Project* demonstrates two views of artists in relation to science. For the Wellcome Trust, art can and should be put into the service of science communication. Unsurprisingly, the artists resisted having their access to the public's imagination manipulated in this way (Zurr and Catts 2005). They had the nearly opposite belief that their role was to critique science and its claims for society.

Indeed, we might expect a good deal of boundary blurring in a world where artists collaborate with scientists, have access to scientific resources, and even hire scientists to work on their art projects or teach in their workshops. At SymbioticA there were role reversals, in which scientists and technicians worked for artists, as well as cases of collaboration in which artists and scientists worked together. For example, the renowned French artist ORLAN completed a residency at SymbioticA and commissioned elements of her artworks to SymbioticA-affiliated scientists and technicians. Such commissioning is quite common, though the bioartists I interviewed had varying degrees of respect for the process. Some contended that it was not possible to be sufficiently "implicated" in the matters of life and death involved with this type of work without hands-on experience.

To an STS analyst, these dynamics do not appear to be dissimilar from those of scientists who conceive of new experimental design and hire others—technicians, for example—to execute the design. In the case of *Fish and Chips/MEART*, the project appears to have been shared equitably with both conceptual input and technical know-how because people who identified both as artists (based at SymbioticA) and as scientists (from Potter's lab at the Georgia Institute of Technology) contributed. The two groups collaborated extensively, particularly on projects with SymbioticA's Guy Ben-Ary. Steve M. Potter's lab published papers in scientific contexts about these projects, whereas the artists developed exhibition opportunities on which both groups collaborated.

ENACTMENT AND EMBODIMENT

Catts is preparing tiny polymer jackets that will serve as the scaffolding for tissue culture. He roughly outlines the jackets with scissors. Crafting a perfectly cut-out coat is not the issue with these prototypes, however. Far more important are the living cells with which the coats will be seeded. Exposing gallery goers to living work is fundamental to TC&A's understanding of the artwork that they are making as part of their investigations of "the semiliving," by which they mean fragments of bodies that depend on technologies and the practices of people to stay alive.

Catts is standing in the small lab space adjacent to what he calls the *halfway house*, by which he means the space designed for artists, or rather the artists imagined by the architects who put an attic room with natural lighting atop the School of Human Sciences at UWA. He always makes it clear that he is glad to have the space but is quick to point out that his work and SymbioticA's work require wet labs. The lab space next door is a fuss of equipment and artworks that I recognize. There is a two-headed calf and a pile of Petri dishes, mismatched glassware, and a pair of microscopes. It is a workspace, but it also must serve as storage and an archive of artworks and installation documentation.

Like most of the research groups in the building, SymbioticA residents make use of shared lab spaces on lower floors. This element of architectural integration parallels the institutional integration of SymbioticA. The need to share resources and equipment is part of the lifeworld of these artists who must continually interact with scientists to engage in their work. For both the scientists and these artists, living things and the maintenance of living things is fundamental to their practices.

Among the points of identity conflict and border policing in the world of biological arts is the key issue whether enactment and/or embodiment is important to this type of art. For example, the summer 2008 issue of the science policy journal *Issues in Science and Technology* featured images from the Museum of Modern Art (New York) exhibit *Design and the Elastic Mind*, including Susana Soares' *Genetic Trace: New Organs of Perception* (National Academy of Sciences, National Academy of Engineering 2008). In this work, Soares suggests that genetic selection may now rely on technology. She imagines additions to the human body to be used for collecting genetic information from others, such as cilia for the ends of fingernails to collect dead skin cells during handshakes.

Living works, such as those created at SymbioticA, can be contrasted with Soares' work and the fiberglass and acrylic sculptures of Patricia Piccinini. Piccinini's *We Are Family* (2003) became an internet sensation. It shows what appears to be a pig-human, reclining and suckling her young. The visually arresting piece stimulates questions about the origins of the being that it depicts. Piccinini hopes that this work and her other pieces that deal with potentially genetically or scientifically altered forms bring to viewers' minds what she calls *the duty to care*, and she explains that we must look after the technoscientific bodies that we create.* In a flurry of forwarded e-mails, people inquired about precisely what Piccinini wanted them to ask: what is science doing with animals? Though perhaps she could not have anticipated that some users would be under the mistaken impression that her hyperreal sculptures were in fact living, she certainly intended to play on their sympathies through their realistic looks. Of Piccinini's work, Donna Haraway wrote, "She invites those willing to inhabit her worlds to dedifferentiate in order to risk bio-engineered redifferentiating as part of a queer family whose members require us to rethink what taking care of this country, taking care of these generations, might mean" (Haraway 2007). Piccinini emphasizes our duty to care for our creations and scientific byproducts. Piccinini's work is nonliving, however, so its demands are very different from a piece such as *Victimless Leather*, which is shown live in the gallery and requires what Zurr calls an *aesthetics of care* (figure 5.2). This functions as an artistic and technical concept adjacent to developments in the context of extending ethics past the traditional boundaries of the human and has implications for making art with nonhumans (Zylinska 2009, Kirksey 2014). Chris Salter (2015) has also suggested what might be thought of as a corollary or an inversion of aesthetics of care, that is, the alien agency of the things that actors create, which have agencies of their own that extend beyond intention. He, like Zurr, derives his insights from close work with the materials of art and case studies in which materiality is central to technological-artistic practice to see what gets made beyond what actors make.

At the end of the day, the museum staff can simply turn off the lights, lock the doors, and leave pieces like *We Are Family* at rest in the gallery. In the case of living biological works, the technical demands are different and often much higher. Controlled temperature, sealed cases, proper

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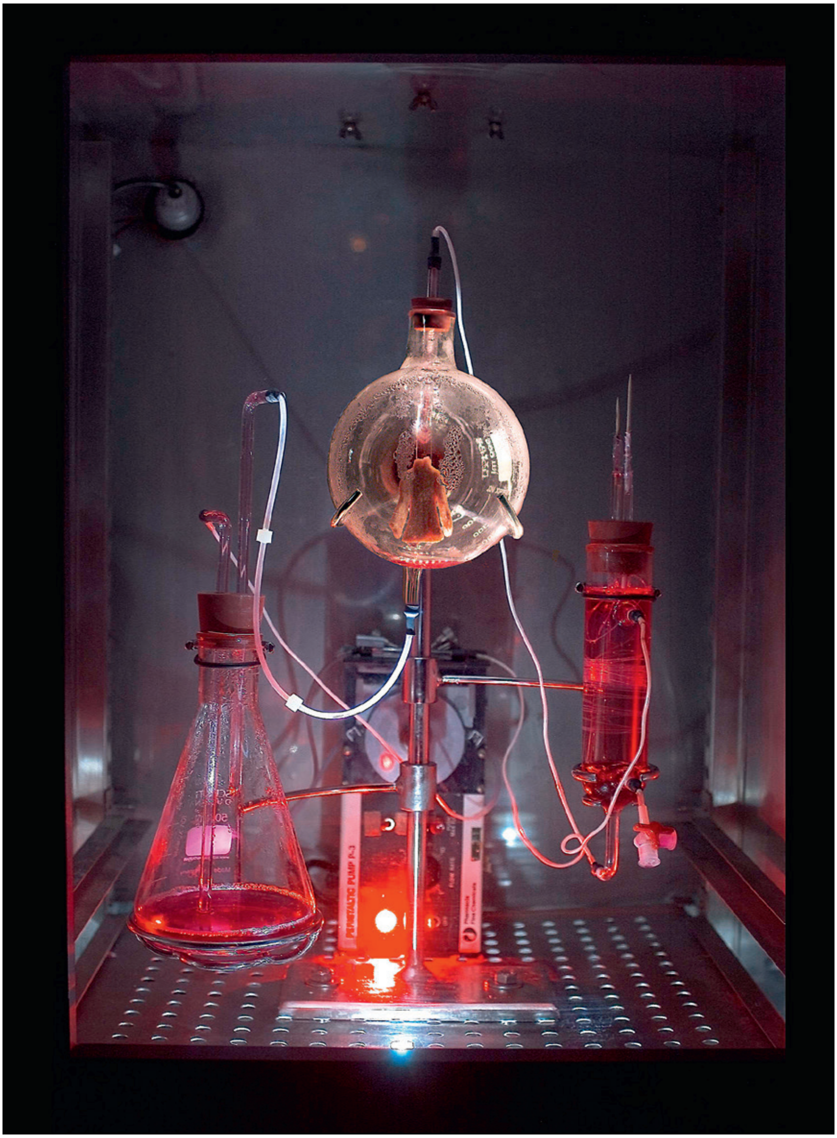
*Donna Haraway recounts Patricia Picinnini's use of the concept of "duty to care" in her essay "Speculative Fabulations for Technoculture's Generations," originally published in 2007 in Piccinini's *(tender) creature* exhibition catalogue. Artium.



5.2 *The Tissue Culture & Art project* (Oron Catts & Ionat Zurr), *Victimless Leather—A Prototype of Stitchless Leather Jacket Grown in a "Technoscientific Body."* Biodegradable polymer connective and bone cells. Hosted at SymbioticA Center of Excellence in the Biological Arts, School of Human Sciences, the University of Western Australia. Art & Medicine Exhibition at the Mori Art Museum, 2010.

heating, correct oxygen levels, and medium changing are often required. These elaborate curation requirements mean that display practices are often influenced by performance art parameters. For example, due to an electrical cut after the installation of *No Ark II* , as noted above, it is unlikely that the cell cultures remained alive overnight. The demands of living artworks sometimes deter curators and are frequently compared to the technical demands of video art in the 1980s and VR in the 1990s. Yet the interest in displaying living artworks persists: it is being in the presence of living things which is the central emphasis for many artists working in this area.

Non-living projects about life, like *We Are Family*, raise the question of the importance of embodiment: is creating the idea of these objects enough or must the objects themselves be produced? Some believe that the practice of making bioobjects, as opposed to creating conceptual representations of them with pictures or models, is central to bioart practice, whereas others believe that this issue is irrelevant to the impact of a bioartwork. *Design and the Elastic Mind* included examples of both kinds of work objects: projects that were primarily meant to provoke thinking and conversation through schematics and images designed as conceptual pieces, and projects that were realized as working, living, or growing objects, rather than representations.

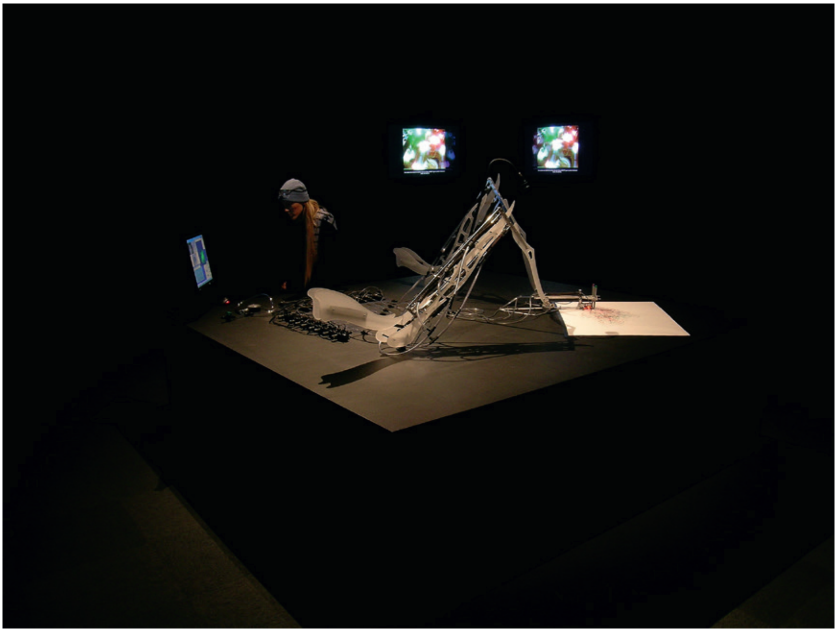
In the case of *Victimless Cuisine*, it is hard to imagine how the demonstrations of eating polymer-based meat could have been completed without creating actual tissue culture meat. *Victimless Cuisine* involved a chef cooking and a group of art connoisseurs and gallery visitors eating culture frog tissues. Some of the same issues are raised here as in *Victimless Leather*. The *Pig Wings Project* does enact the difficulties of creating and supporting even a small and unusable tissue culture organ. Curators have become adept at dealing with new media and showing interactive and technical works in the gallery, despite technical parameters that these works impose on the gallery space and staff. This is not without precedent, because new art forms have always involved new forms of curation, the most recent example being the incorporation of video art pivoting into interactive digital arts (Grau 2007). It seems that there is no system in place, however, to consistently deal with biological works. Because of the ethics, perceived safety, and technical demands, a philosophy that these works should be shown live in the gallery ensures that today's biological artist will need to travel with the artwork to ensure that its technical needs are met. These needs also reflect the way in which performance-based artistic practices have influenced contemporary hybrid arts such as bioart. This relationship is an opportunity to reflect on the links between the performative aspects of the biology and the performance art traditions in the visual arts.

At the moment, there is no consensus within the bioart community about whether enacting or embodying artworks is more valuable or more interesting than simply representing ideas in a nonliving form. It certainly is true that many bioartists have strong opinions on this issue and often evoke rhetorical resources such as ethics or honesty in representing life to the public. Some believe that representing the living in projects is sufficient. For example, Piccinini's lifelike sculptures made of plastics avoid some ethical problems while causing others. Other observers believe that to be authentic and ethical, projects should contain actual living material (for example, SymbioticA's tissue cultures). Even in these cases, sensitive materials are liable to die, so the artists are often showing the dead, rather than the living. Living artworks vary widely: from simply presenting living things as artworks, to showing works whose living status is ambiguous, to presenting as living what the artist knows (in the Schrödinger's cat) sense are dead, owing to the conditions in which they have been placed in an art gallery. For example, TC&A's *NoArk II* (2009) was exhibited for the *Superhuman: Revolution of the Species* Australian Network for Art & Technology (ANAT) and the Royal Melbourne Institute of Technology (RMIT) at the RMIT Galleries, but when the museum technicians turned off the electricity to the gallery at night, the bioreactor's contents were most assuredly dead (though the artists did not test them) because the cells were deprived of all the bioreactor's functions. This complication should raise questions about the ways in which science museums and centers create representations of science and about what counts as *working* in those cases. In some science centers and museums, and in many other venues in which science and technology are demonstrated, simulations and mock-ups are commonly used. In some cases, there is no real counterpart anywhere, and questions can be raised about the feasibility or misleading impressions given by the mock-up.

In this world of contemporary art, lay viewers frequently assume that the artist will be dealing with fictional and imaginative worlds, and this, too, raises questions. Does it matter if it is what we say or imply it is? Meanings or resonances can be created around art materials, differentiating them from the meanings that they have in the scientific community. Yet those dealing with scientific materials and displaying scientific equipment, as SymbioticA artists do in the case of *The Pig Wings Project* and *Victimless Leather*, are playing on the power and belief in the "truths" uncovered by the scientific community in our society. Even if the aesthetic and technical qualities of the pieces are further developed, the central concept does not change. Rather, viewers are offered different physical objects to consider. We are offered alternative wings, but the idea of the creation of the wings and what this means for our genomic dreams remain the same. We are offered a jacket that might avoid the use of animals, but in the end we find that it requires bovine calf serum, so our dream is thwarted again by the materials themselves. This layering of meanings—drawing on the power of scientific protocols and techniques but displaying them in the art community as artworks—has the effect of absorbing the cultural power of science while critiquing the science that these works implicate. Works like these necessarily complicate the relationship between art and science, not simply by placing science artifacts in a new context, but also by reconfiguring their attached meanings. Tissue culture engineers are not expected to create new organs from mythical animals, and yet popular depictions often suggest that scientists are interested in doing or exploring whatever is possible. The reaction to this project allows us to consider for a moment the apparatus that makes credible the scientists' claims to do the seemingly impossible in the near future.

THE IRONIES OF FAILURE

Exit Art's (New York) Corpus Extremus (Life+) included *Silent Barrage* (2009), a set of poles designed to facilitate interaction between gallery goers and fish neurons at Steve M. Potter's lab at the Georgia Institute for Technology. No one seemed to be sure they were working, however. This piece was a descendant of *Fish and Chips/MEART* (2001), the first full-scale



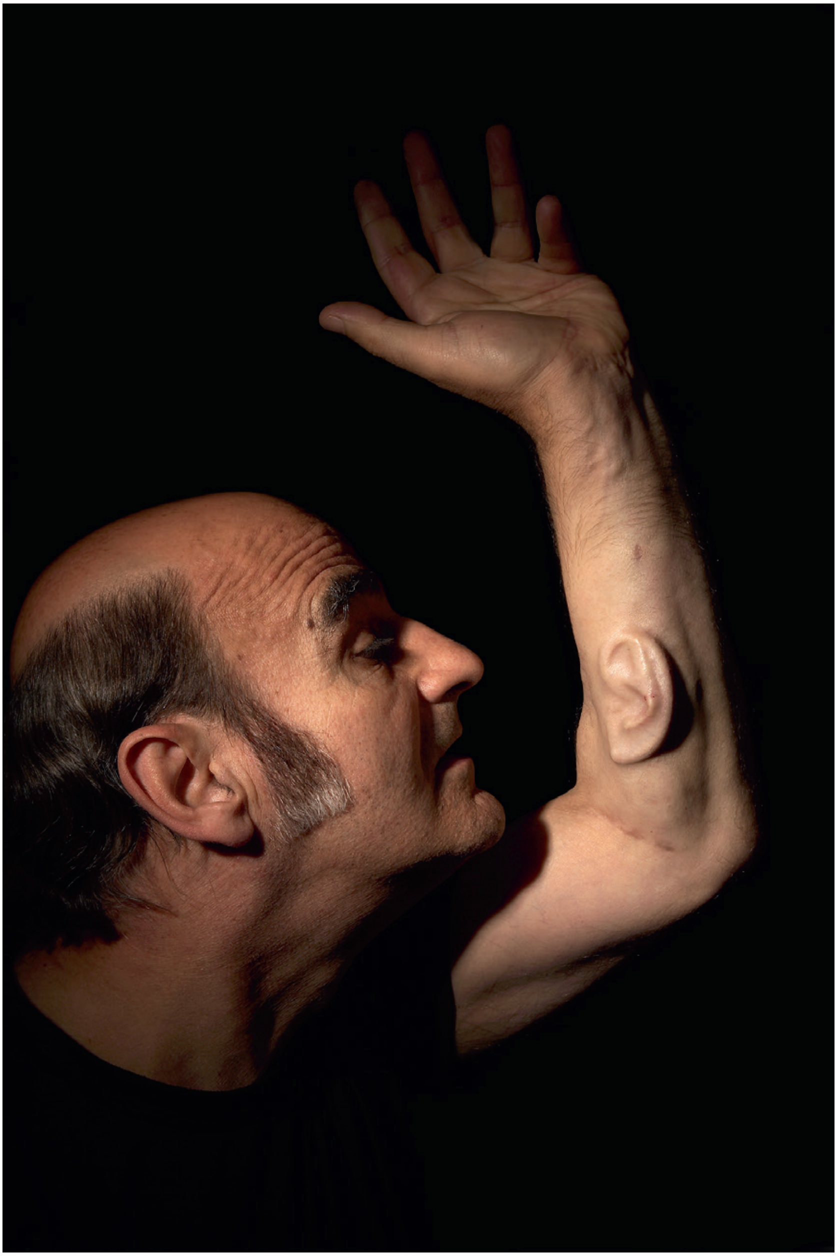
5.3 SymbioticA research group in collaboration with the Potter Lab, *MEART—the Semi Living Artist.* Neurons from embryonic rat cortex grown over a multielectrode array, robotic drawing arm, internet connection. Australian Culture Now, 2004.

SymbioticA project, and involved the collaboration of artists and scientists (figure 5.3). Fish neurons from Georgia Tech were connected to an internet-based software program that translated their pulses into motion of a robotic arm, which drew lines based on the pulses. In the Exit Art installation, the artists made use of embryonic rat neurons in Potter's lab and programmed a feedback loop so that visitors interacted with a set of metal poles arranged in the middle of the exhibit space. The poles were fitted with robotic disclike forms that moved up and down vertically based on the input from the rat neurons in Potter's lab. Like *MEART*, *Silent Barrage* was a drawing system: the discs that received the rat neuron input moved up and down and marked the poles, which were covered in paper.

The setup of the piece extended into the opening of the exhibition. The artists were working to get the neurons connected via the internet, but all the while visitors, not knowing that the artwork was not working in the way that it was designed, were moving throughout the space. Whatever it was that these visitors were experiencing, they did not appear to be aware that the piece was not yet functioning, and this raises questions about what we mean when we say an artwork or scientific apparatus is working.

What counts as success in the biological arts community is contested in that community. One illustrative case was Stelarc's attempt to create an ear on his arm, through which he planned to feed sound through a microphone implanted in his arm to the web (figure 5.4). He was unable to execute this plan when the implant became infected, but he did not frame the episode as a failure. Nor did he erase the online evidence of his plan. Instead he has continued to work with the project. Stelarc has received much media and academic attention for his attempt to interface his own body more directly with technology, so in this sense the project could be considered a success (Smith 2005). The infection event contradicts Stelarc's stated philosophy that "the body is obsolete" and can be improved by technology (2005). The event of his infection did not dissuade Stelarc from his philosophy; he might have had many opportunities before this to notice the apparent contradiction between his work and philosophy. His early art performances (Stelarc 1976–1989) involved hanging himself by hooks from various platforms in public places. The piece created tension, quite literally, in Stelarc's body between his desire for the feeling of flying and the pain and distortion of the hooks piercing his back flesh, which enabled the flight. Critiquing the contradictory nature of this philosophy, however, only makes sense if we accept that Stelarc is speaking like a scientist, not like a character attempting a critique by demonstrating what happens when a set of beliefs is carried out.

Stelarc's infection can be interestingly contrasted to the death of the cells in *NoArk II* when curators turned off the electricity afterhours or in *MEART* on occasions when the connection between the museum piece and the lab were down so that the arm had to run without impulses from fish neurons. These episodes raise questions about what effects these ruptures have on audience perceptions and bioart community standards. Perhaps people in the bioart community are allowed to hold opposing beliefs, to say and do contradictory things and not be considered hypocrites, or even have other community members point out their logical problems. Confidentially, other bioartists are willing to point out



5.4 Stelarc, *Ear on Arm*. London, Los Angeles, Melbourne, 2006. *Source:* Photographer: © Nina Sellars. Courtesy of the photographer.

the inconsistencies in Stelarc's position. On the other hand, it is equally plausible that Stelarc is merely playing a role as a performance artist parodying the belief that the body can be improved through technology. In other words, the seeming hypocrisy is Stelarc's character's interacting with the artist's body to point out the impossibilities of the philosophy that the artist holds. Like SymbioticA, in any event, Stelarc points out the contingencies of life in the body.

The Pig Wings Project exhibits its own ironies. The artists used the term *genohype* to subvert the Wellcome Trust's eagerness to publicize the genotype Human Genome Project and its potential outcomes, but SymbioticA attempted to take advantage of this platform to bring attention to their views of the value of the genome and to their artwork. Ironically, *Pig Wings* is a demonstration against hype, but the articles and letters and the piece itself are about drawing attention to a different opinion. This political dimension is very present in some strands of contemporary art, and the *Pig Wings* episode shows how artists can subvert and react to the expectations that the science world and even galleries have for science-engaged artwork (figure 5.5, figure 5.6, and figure 5.7).

CONCLUSION

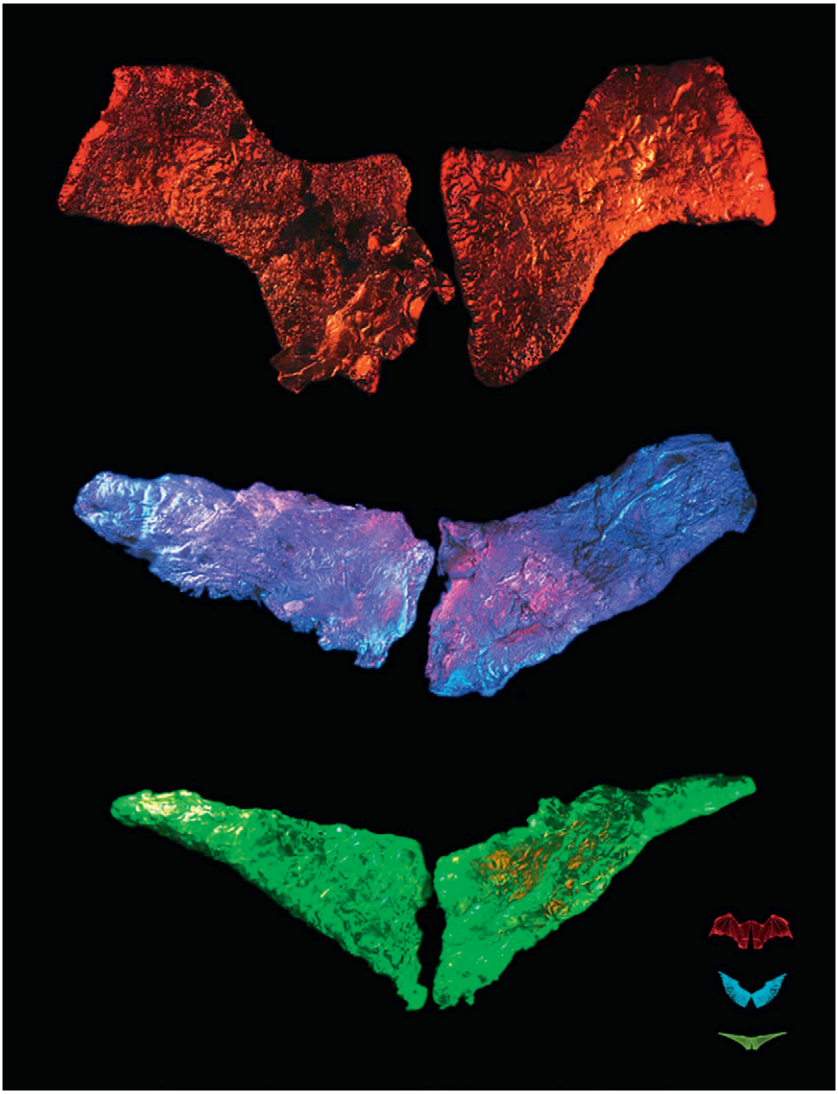
Those gathered are all wearing white lab coats and observing a man looking into a microscope. He is talking, and they are taking notes. A graduate student who works in the lab is talking about form and color in microlife and what is down there under the lens. He adjusts the microscope and stands up so that the first student can sit down. Stacked petri dishes await swabs. He asks how many students are familiar with the use of fluorescent bacteria. A few hands go up. Examples of images, mostly landscapes, made of glowing bacteria growing in petri dishes are projected onto the laboratory wall. The attendees are art students, and this is an art class at SymbioticA. Bioart plays on popular ideas about the role of science in society to interest us in knowledge making processes while *undermining* these ideas, complicating definitions of life in ways that science cannot resolve. Paralleling Eagleton's understanding of aesthetics, SymbioticA aims to highlight the "messiness" of the life of the body and lived experience. Its artists seek to make explicit this uncontrollable quality,

5.5 *Cell harvest.* Oron Catts, together with a scientist, harvesting pig mesenchymal cells (bone marrow stem cells) for *The Pig Wings Project*. *Source:* Photography by Ionat Zurr, 2000–2001.

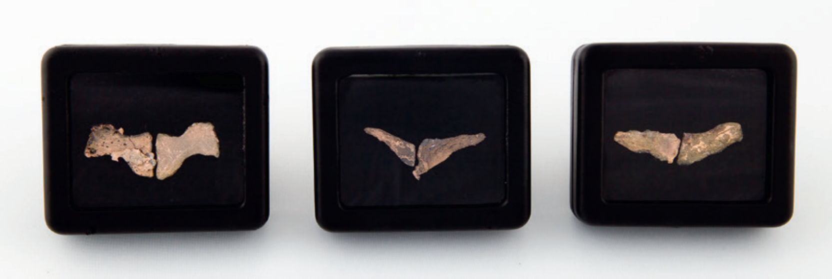
codifying and materializing it in bioartwork. Their project complicates the scientific community's high modernist assumption that biotechnology can still account for and comprehend the complexity of the very living systems that it must simplify for purposes of study.

In engaging these contradictions, artists at SymbioticA have introduced concepts such as the aesthetics of care. For Eagleton and many bioartists, aesthetics confront what science ignores or reifies. If the aesthetic is political, in the sense of the uncontrolled part of society's experiential life, science studies should take this quality into account when it applies its tools, which are already honed to deal with the experience and practice of science and technology.

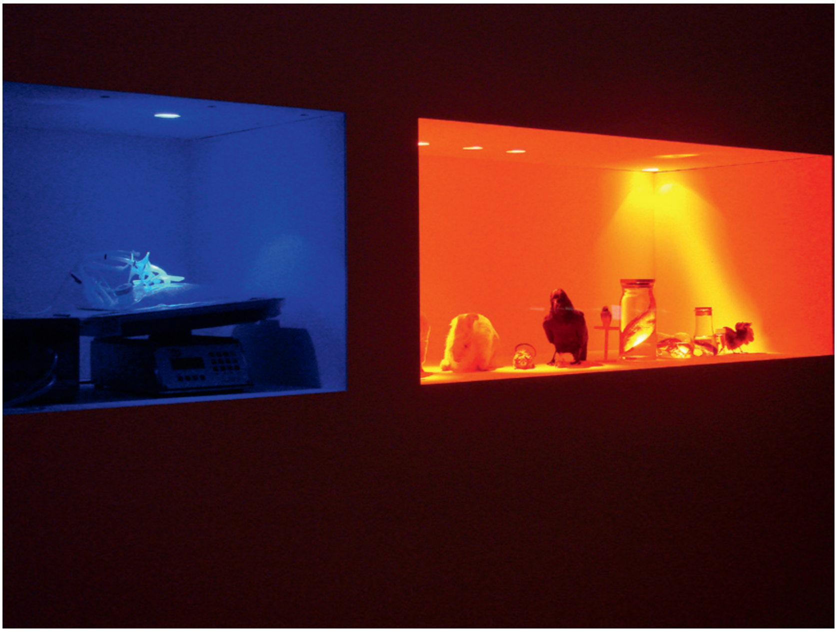
Indeed, in a bioarts project and its observation of the limitations of the biotechnological sciences and the logic of capitalism, STS scholars may recognize a kindred spirit. SymbioticA artists gather material and rhetorical resources to make their projects count as critiques of science, while



5.6 *The Tissue Culture & Art Project* (Oron Catts, Ionat Zurr, and Guy Ben-Ary), *The Pig Wings Project.* Pig mesenchymal cells (bone marrow stem cells) and biodegradable/bioabsorbable polymers (PGA, P4HB), 4 cm × 2 cm × 0.5 cm each, 2000–2001. Hosted in SymbioticA—The Centre of Excellence in Biological Arts, School of Human Sciences, the University of Western Australia.



5.7 The *Tissue Culture & Art Project* (Oron Catts, Ionat Zurr, and Guy Ben-Ary), The Pig Wings Project. Pig mesenchymal cells (bone marrow stem cells) and biodegradable/bioabsorbable polymers (PGA, P4HB), preserved in gold and displayed in jewelry boxes, 4 cm × 2 cm × 0.5 cm each, 2000–2001. Hosted in SymbioticA—The Centre of Excellence in Biological Arts, School of Human Sciences, the University of Western Australia.



5.8 *The Tissue Culture & Art Project* (Oron Catts & Ionat Zurr), *No Ark II*. Biodegradable polymer connective and bone cells. Hosted in SymbioticA—The Centre of Excellence in Biological Arts, School of Human Sciences, the University of Western Australia. *Corpus Extremus (LIFE+)* at Exit Art, New York, 2009.

employing scientific methods and positioning their work as artistic practice. In so doing, they have created a fused identity, one that allows them to move biological practices into art galleries and make political points about science using artistic logics. They distinguish themselves from those that they think of as science communicators working for science. Their ideas about science may sometimes align with the goals of scientists, as is often the case in ecoart and ethical critiques of farming practices, but they see themselves as working for their own agendas beyond science. Several SymbioticA researchers once poked fun at a science communication prize that they had won, comparing it unfavorably with "real" accolades from the art community. They seemed to believe that the award did not fit their work and that the group conferring it understood them in an "unironic" way.[3] Works like *Fish and Chips/MEART* bring together ideas from neurobiology and robotics to probe the nature of creativity and of minds. *Victimless Leather* sets up questions about the use of living things as gallery objects and the ethical issues involved in biological practices as common as tissue culture. In contrast to the view that artists are parasitic to science, *The Pig Wings Project* revealed how artists can be employed to hype scientific ideas and how artists can react to such attempts to enroll their work in other agendas.

No less than scholars in the fields of sociology, history, philosophy, anthropology, and literature, bioartists attempt to engage deeply with the form and content of scientific work. They engage some of the same issues that STS engages, not by publishing papers but by vesting ideas in physical and tactical objects. They use the substances of science as the means for sometimes sardonic, sometimes playful aesthetics to help us rethink what science means by life. As critical agents, SymbioticA, as well as bioartistic practice more broadly, is suggestive of science studies by other means.

6

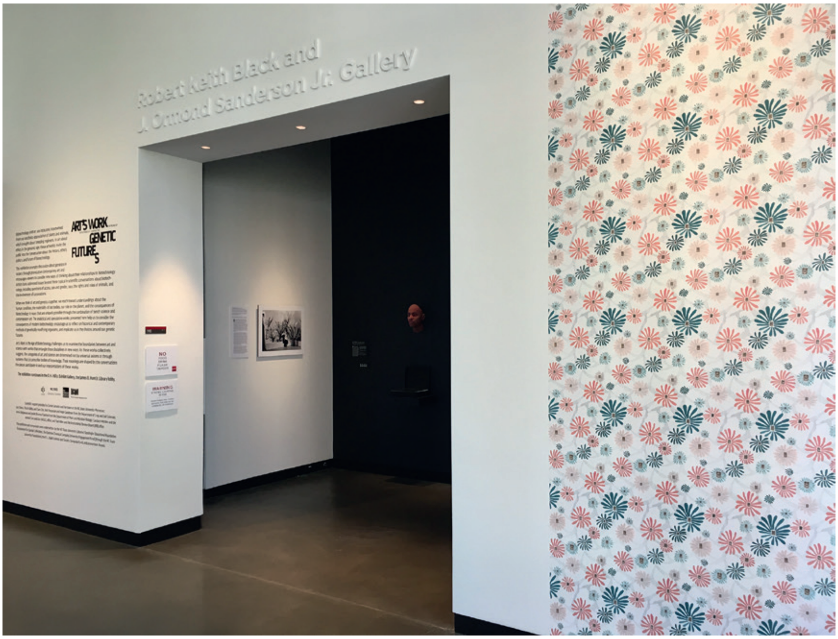
CURATING ART'S WORK IN THE AGE OF BIOTECHNOLOGY

Exhibitions are social and political interventions. As an STS scholar and the curator for art and science exhibitions, I have long been interested in exploring the critical analytical potential of exhibitions on biotechnology that raise social and political ideas and consider ways in which artworks, particularly those that involve scientific expertise or technical materials, are understood by visitors. As an analyst, I am interested in reflecting my own role as a curator in reinforcing or dimensioning visitors' senses of how projects, objects, and people are understood as art or science.[1] Participant-observer work and its relationship to autoethnography are well-recognized ways of entering STS research. In my capacity as an independent curator for art and science exhibitions, I have been well positioned to interact with artists working with science and to learn about curatorial norms but also to shape what the role could be for an STS scholar and to attempt to make STS points through material means. Until I began curating in 2012, I had been in a position only to observe others making arguments through materials. As a curator, I had to make the case for how objects and people fit into the knowledge communities of art and science. The positioning that I had observed was now my job.[2] The work of the curator makes explicit aspects of the effort that other actors put into positioning work in art and science contexts and in producing interpretations of assemblages of exemplary objects.

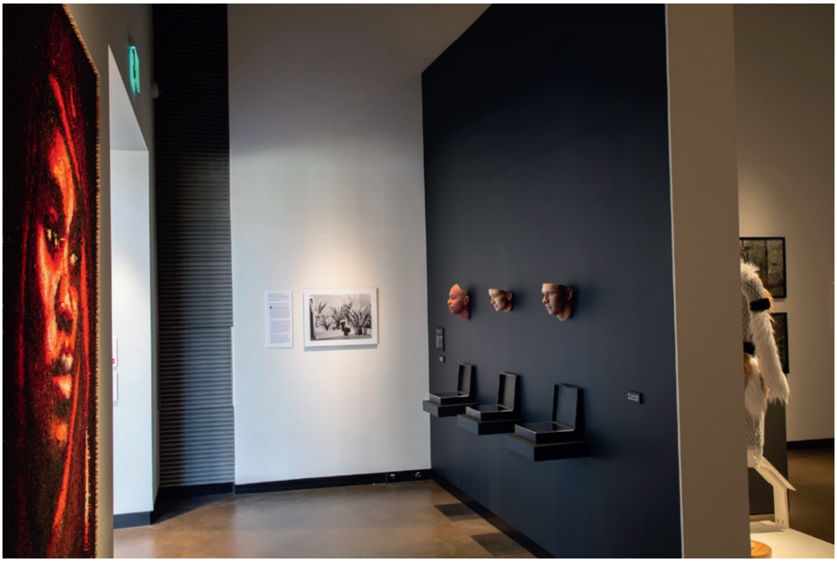
At the same time, there is a growing corpus of materials from scholars who aim to integrate art curation techniques with those derived from science, especially natural history contexts (Garcia and Normand 2019). In this chapter, I explore curation as a generator of ASTS-relevant knowledge and consider the ways in which materials and rhetoric can be brought together to position works as art or as science. This mode of curation functions as a distinct way of knowing and interpreting the liminal knowledge embedded in art and science boundary objects. In the following case study, I examine how practices of curation may be informed by the critical approach of STS in setting liminal art and science works into their contexts as knowledge forms. This hybrid practice constitutes a reflexive epistemology that serves both to illuminate emerging new forms of knowledge and to suggest ways of understanding that knowledge. In this case study, I reflect on the curatorial experience of my team in situating art-science work in an exhibition held at North Carolina State University in 2019–2020. *Art's Work in the Age of Biotechnology: Shaping Our Genetic Futures* was a multisited exhibition and research program stretched over four years from its initial conception to execution (figure 6.1, figure 6.2, and figure 6.3). The exhibition took a novel approach to curation that involved an open call; input from artists, scientists, humanities scholars, and members of the public; and respondent-oriented programming designed to focus attention on the issues brought forward in the artworks.[3]

CONTEXTUALIZING CRITICAL CURATION

The project team consisted of members of North Carolina State's Genetic Engineering and Society Center, including Director Fred Gould, Todd Kuiken, and Patti Mulligan; North Carolina State Libraries' exhibition programs, including Molly Renda, Christ Tonelli, and Chris Vitello; and the North Carolina State Gregg Museum of Art & Design, including Director Roger Manley and the museum staff. The final exhibition was held Summer 2019-Fall 2020 at the Gregg Museum of Art & Design, the physical and digital display spaces of the college libraries, and the North Carolina Museum of Art (NCMA). These exhibitions opened with a two-day symposium featuring respondents discussing particular works—which


Robert Keith Black and
J. Ormond Sanderson Jr. Gallery
ART'S WORK
GENETIC
FUTURES

6.1 View of gallery entrance from interior of *Art's Work in the Age of Biotechnology*, Gregg Museum of Art & Design at North Carolina State University, Raleigh, NC. *Source:* Photograph by Matthew Gay, courtesy of the Gregg Museum of Art & Design, 2020.



6.2 View of gallery interior of *Art's Work in the Age of Biotechnology*, Gregg Museum of Art & Design, North Carolina State University, Raleigh, NC. *Source:* Photograph by Matthew Gay, courtesy of the Gregg Museum of Art & Design, 2020.

6.3 View of gallery, *Art's Work in the Age of Biotechnology*, Gregg Museum of Art & Design, North Carolina State University, Raleigh, NC. *Source:* Photograph by Matthew Gay, courtesy of the Gregg Museum of Art & Design, 2020

hailed from disciplines as diverse as bovine breeding and anthropology—and members of the public as well as panel discussions on subjects on which clusters of artists had worked.[4] In addition to targeted programming from the Genetic Engineering and Society (GES) Center and the Gregg Museum, the exhibition was part of the GES-sponsored Margaret Atwood event. Atwood had inspired some of the pieces in the show. The writer visited the exhibition and discussed some of the pieces, particularly Charlotte Jarvis's *In Posse* and Suzanne Anker's *Laboratory Life (for Oryx and Crake),* named for characters created by Atwood.

The initial program involved a pop-up exhibition called *Field Trial* held at the Contemporary Art Museum (CAM) of Raleigh, NC, in 2017, accompanied by a symposium that brought together artists, scientists, and humanists for conversations about how the show should be structured and framed.[5] More traditional exhibitions at museums and art galleries tend to involve one-way, top-down communication that conveys, perhaps unavoidably, a message from an unseen expert. In such a format, the curator or institution declaims to the public, interpreting objects with a view to fostering an experience for the viewer. Modern museum staging techniques that highlight important objects derive from traditional treatments of western religious relics intended to stimulate a psychological effect of wonder and reverence. Many of the same material interventions, for example, the use of plinths to elevate and highlight objects, are still in use.[6] The production of experience relies on the tension between direct proximity to the object and distance from it. Such stagings found their way from cabinets of curiosity into art and natural history collections (Garcia and Normand 2019) and, with moderate modifications, into the contemporary white box gallery and science center. Awe and wonder continue to define visitor expectations in galleries and museums, and even experienced critics look to encounter the sublime or at least the unexpected.

Although some of these techniques using proximity and distance were at work in *Field Trial* at CAM, we also drew on science-center traditions that overlap with interactive art concepts. *Field Trial* asked museum-goers to go beyond more predictable hands-on experiences and to hold discussions about the pieces and the issues that they raised. In effect, I applied STS and science engagement principles to the exhibition and sought to enlist the user in the knowledge-making process, a method increasingly used by art-science curators. This was a research-oriented approach to an exhibition, rather than a more traditional approach of a single curator or a small curatorial team developing the complete plans for a show. This method sought to model a more inclusive way of creating an exhibition that involved many voices and inputs from the public. To give audiences a taste of what was possible rather than asking general questions about what might interest them (which might be limited to media or subjects), *Field Trial* sought to place individuals outside the curatorial team in a position of power to respond to, comment on, and critique what they were experiencing.

This approach was an attempt to address two problems. First, occasioned by deliberative forums and responsible research concerns, facilitators have wished to place the public in conversation with scientific experts for the purpose of considering public choice and policy. This has brought to the fore questions about how much technical knowledge that members of the public require to adequately engage in such conversations. This situation can lead to an inverted relationship from the one typically understood as the reason for such programs: scientists want to discuss scientific findings with political implications. such as climate change, or emerging technologies, such as nanotechnology or genetically modified foods, with the public, and policymakers want to listen to the public's views. This process, however, is initiated by setting members of the public into a pedagogical recipient position.[7] This leads to a heightening of some aspects of self-selection among participants toward those who want to be active learners, particularly about scientific subjects. At least initially, it tends to position them as passive receivers as information is presented, which sets the stage for the conversation that has been formulated, without much or any information about the individuals themselves or their particular interests. Important reframing of this question has been offered by Arizona State University researchers working on the subject of nanotechnology and attempting to engage the public with the context of scientific choices, because it is this expertise, which the public already possesses, that is necessary to make democratic choices (Guston 2014; Wynne 2011). This is a workaround to the science communication problem of science "deficit" models, in which a lack of agreement with science experts is understood as a deficit of knowledge on the part of the public (Craig 1999). Engagement and an emphasis on conversation (multiway communication) has been an important solution developed in science communication.

For *Art's Work in the Age of Biotechnology*, I hoped to avoid at least some of these problems through iteration: by offering the public and experts from science, the arts, and the humanities access to some possible outcomes in an informal environment in which the team sought nonhierarchical engagement. Rather than presuming that the public needed a set of knowledge about biotechnology in advance, contextual and scientific materials that were part of the artworks were presented simultaneously with aesthetic and experiential content. Visitors were asked directed questions about that content, which set them up in a role less as a pupil and more like that of a critic, who observes and oversees work sought from the public. Responsible research and innovation (RRI) initiatives and deliberative forums desire public comment on what they see in the work rather than placing the public in an educational setting or asking them to explain the content by rote as a precursor to debate.

A second important problem that this method tried to address is a structural problem with exhibition and one-off programming: there are no second chances. Even well-prepared findings from audience surveys can be difficult to use, because the industry practice is generally to hold an exhibition online after it has appeared in a given institution. Curatorial principles and best practices derived from other shows are, of course, employed, but scant specific information is available. This is true for museum professionals working in both art and science. Although audience feedback and data sets are important tools for understanding users and for showing the effects of the exhibit for scholarly and fundraising purposes, it is not usually possible to discover something specific about an aspect of the exhibit or to edit or adjust that element to create a more effective exhibition. By the time that the data are gathered and processed, the show is closed. There are, of course, caveats. For large institutions with repeated exhibitions of similar content, it is possible to glean information from one way of presenting a set of ideas for use in the next exhibition, but very often a particular exhibit on a certain subject is shown in a given institution on only one occasion. This limits the ability of curators to recursively learn from the same materials. Findings may be useful to other curators in other places if the exhibition travels; this is certainly not to say that such data gathering is not important, only that it has limitations for the exhibition at hand.

To at least partially address this problem, our team hoped to use information from the pop-up exhibit that would be representative of some of the proposed concerns, themes, and media types in the exhibition and in the open forum of symposium discussion well in advance of the major show. In this way, we could think about what works and curatorial choices functioned best and use those to shape the resulting exhibition. This would give a wider range of voices expression in the final exhibition and help avoid making discoveries too late about patterns of viewer preferences or unwelcome omissions in content and presentation. Instead of attempting to measure public opinion about biotechnology, which tends toward elicit generalization and detracts from engagement, the questions posed to audiences asked for qualitative responses to the artworks. Participants were encouraged not to give their views as a measurable outcome of their formal or informal science education experiences but to act in a role closer to that of the critic. Rather than trying to gauge whether audiences understood information about, for example, paleogenetics from Christina Agapakis' *Extinct Perfume*, the exhibit was designed to prompt viewers to think about whether biotechnologies could, in their view, adequately replace conservation efforts.[8] This particular piece displayed three speculative aromas based on an extinct flowering plant (*Hesperelaea palmeri*), created using conventional perfuming techniques. Questions were intended to enhance reflection and to suggest the audience's agency in the process as well as the value that the team placed on the viewers' ideas and experiences connected with the installations.

After the pop-up exhibition and symposium, preparations for the major exhibition would begin. The nature of exhibitions not purpose built to their spaces is that they are ephemeral. Few galleries have the capacity to permanently locate installations. The artworks persist, but the context of the exhibition and other pieces by which an artwork is read are no long present; this probably accounts for the effort put forth in documenting an exhibition. An exhibition is a knowledge-making event, albeit usually a temporary one. As in the case of an experiment, temporary knowledge is embodied in the exhibition that cannot be stored and is not persistent beyond the evidence produced by the assemblage: the phenomenon of the experience of the exhibition is gone. When an experiment is disassembled or an exhibit is packed away, only documentation of the knowledge making moment persists. Yet this exhibition aimed to learn from its pop-up and to use that information to structure the major exhibition. The aim was to create a selection of possibilities—in terms of artworks and themes—that could be presented to audiences in the same geographical area and contacted through the same means that would be used for the major exhibition to get a sense of some ideas and artworks that worked well from our perspective as the curatorial team. We also used a small selection of questions posed to audiences about the artworks. Because I wanted to offer a space for inclusion of expertise from across the art-science spectrum, we asked attendees at the *Field Trial* to express their orientation toward the work on either a Post-it note wall or an iPad. There were questions about each installation. This effort was led by Todd Kuiken with assistance from the middle school docents at CAM.

Following the *Field Trial* and day-long workshop/symposium, the team developed a set of goals for the show, which were translated into criteria for artist selection. An open call was held, followed by interviews. Works were selected based on those parameters, then further chosen using diversity criteria (location, medium, race, gender) to formulate the final slate of artists. Such an exhibition sponsored by a university has many goals, but among them are inevitably concerns about what the exhibition projects about the areas of science and art.

As the curator for this project, I have sought to follow Stirling's call for avoiding oversimplification. Instead I kept things as complex as they were for viewers and resisted the temptation to communicate a simplified science or the art-science relationship. Rather than avoiding the more fraught and complex issues at play and how the knowledge from each of these areas of inquiry might be presented, I tried to allow this complexity to remain by not explaining artworks but instead raising questions about them. This was especially true in the context of wall texts, which provide the narrative guidance for viewers in an exhibition and are therefore a tempting place to explain installations rather than encouraging viewers to see the issues at play for themselves. If art and science curators communicate a simplified science (that is, one not problematized by STS), we communicate incorrect science, in science communication terms (Halpern and Rogers 2022). The artist's contribution is to unpack science and to offer entryways to its complications and alternative possibilities, which help us understand the complexity of science.

WHAT ARTISTS OFFER: SHAPING OUR GENETIC FUTURES

Art's Work in the Age of Biotechnology was designed to elicit discussion about biotechnology in society through contemporary art to offer viewers new ways of thinking about their role in determining and responding to these developments. The works selected were both analytical and speculative, and they asked about practices and projected possibilities for the meanings of art and science in different contexts. The exhibition aimed to engage the public about the social uses, familiar and new, that biotechnology might offer through artworks that dealt directly with biotechnologies or offered new ways of contextualizing them. Artists in the show were selected because they addressed questions beyond those typical in scientific conversations about biotechnology, including questions of access, sex and gender, race, the rights and roles of animals, and the involvement of corporations.

Soliciting conversations about emerging technologies, such as biotechnology, with the public often creates a tension between how much information and detail to provide versus encouraging visitors to value what they already bring with them to the dialogue (Martin and Tait 1992). Science communication scholars have argued that it is important to avoid the *deficit model*, the assumption that if the public disagrees or expresses ideas not in concert with the reaction that scientists or science communicators expect, then there is a deficit in science communication (Allum et al. 2008). The usual response is that more communication, in the form of additional information, is needed. In this model, there is no route by which the public may legitimately disagree or even raise serious issues with the science presented to them (Davies and Horst 2016).

For curators, this can create a roadblock: how much information should we provide to visitors? At what point may we be distracting from the conversations that we want visitors to have by adding details that may be unapproachable or even alienating to the very people we hope to draw into dialogue? There will, after all, always be technical unknowns, particularly in the case of emerging technologies. Particularly for me as a curator, it was important not to place the visitor in a pedagogical role, which might subsume the important role that the public should play in shaping such technologies. Art and science together have a way around this inclusion conundrum. Rather than emphasizing technical details that audiences are meant to master before becoming part of the conversation as lay experts, these liminal works challenge the viewer to think about the effects of these technologies, starting from the big picture of social, political, and ethical context. Rather than the small picture of, for example, precisely how the technology of CAS9-CRISPR can be used, how *Trifolium repens* might be bred to produce more four-leaf clusters, or how hox genes affect embryonic development, artists began by asking what people will or should do with the power to edit their own genomes and what it would mean culturally if, for example, we could create mermaids or if all clovers had four leaves. Maria McKinney's *Double Muscle* (2016) film and sculpture, made of colorful bovine semen straws, comments on the traditions of cattle breeding that have been altered through new biotechnological processes.[9] Because the hox gene is responsible for muscle growth regulation, the sculpture was fitted to the body and context of the Belgian Blue. Through 150 years of linebreeding, Belgian farmers managed to manipulate this gene, before modern biotechnological tools, to achieve the "double muscle." The semen straw sculpture is harnessed to the animal's body and moves between shadows and light, giving viewers visions of parts of the sire's body and the colorful sculpture. The work implicitly asks visitors to consider what we have already wrought: the sociotechnical and biotechnical landscapes brought about by these new technologies.

It is with these social, political, economic, and cultural effects that societies must grapple. These are questions about which we may all have an informed opinion, formed by individual daily experiences and fueled by interpretations of artworks that address these subjects. Scientists are specialized enough to handle the details: ASTS aims to mobilize artists to help us access new knowledge about science and to develop our own ideas about science- and technology-related issues as well as helping curators understand their roles as facilitators and mediators such that they understand themselves as practitioners of ASTS methods. Along the way, visitors to art installations learn about biotechnologies but in ways that are relevant to the choices that society collectively and individually faces. The expertise that artists provide facilitates important conversations about biotechnology that are not technical but social. The expertise that they provide is a way to expand the conversation in an accessible way, not absent technical details but open to the values and concerns of the public who are experiencing the art.

This exhibition was created to engage the public about the social uses, both familiar and new, that this technology might offer, through provocative art that dealt directly with these technologies or offered new ways of contextualizing them. Dimensions of both biotechnology and art were on display throughout this exhibit. Viewers' perceptions of art and science shape the politics of meaning ascribed to the pieces in the exhibition. Institutional settings have a major impact on audience perceptions that a work is art or is science. Given the conditions of this exhibition—that it would be located both in art-related buildings and galleries and in university libraries, but with financial support from the GES—the team agreed that works were likely to be initially received as art. Therefore, to situate the pieces as both art and science, choices about display needed to be made to focus visitor attention on the scientific research aspects of the works. These initial conditions became the basis for considering how audiences might be introduced to this work and how, with limited text and some physical gallery limitations, the exhibition might offer an integrated impression that would enable further conversations about biotechnology and art.

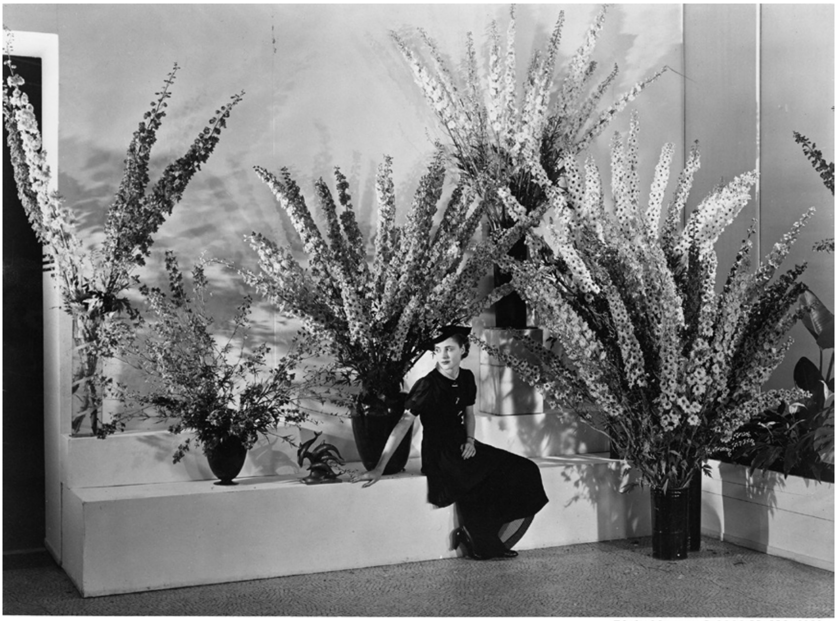
HISTORICAL POSITIONING THROUGH RHETORIC AND MATERIALS

To offer visitors an integrated sense of the artworks, the show was contextualized using the history of art and the history of biology, especially around breeding practices. The exhibition offered historical modes as a way to access the lineage of agricultural breeding practice. On the other hand, the use of history can complicate viewers' interpretations of the exhibition: attempting to situate biotechnology in a longer history can have the effect of normalizing or even naturalizing genetic interventions. By showing the lineage of humans working with traditional breeding techniques, to some degree the viewer may take away the suggestion that there is nothing new happening on a larger scale. At the same time, novelty or the difference between new genetic interventions and past technologies has the potential to excite the public and funders about the technology. This emphasis on the tension between lineage and the newness of these technologies was at play in curating this exhibition. It would be incorrect to suggest that there is substantive novelty in artists working with biology or indeed in human manipulation of genetic traits; at the same time, too much emphasis on this point might suggest that the ethical, political, and social issues that the exhibition intends to raise are settled or less pressing questions. To try to deal with these issues, the exhibition team wanted to tell a history of involvement with genetics but also to make clear the related persistent issues with equity and these works. If rhetoric were our only tool, all this could be accomplished in the space of short wall texts. Fortunately, raw materials, including artworks, physical space, and a history of exhibition techniques, are available to assist in positioning the pieces and in stressing these potentially oppositional ideas.

The exhibition text argued for an intertwined history of biological and artistic intervention through wall texts and material installations. This was done in two ways: first, by recalling the history of agricultural practice with an emphasis on culture, and second, by recalling a historical episode often invoked by bioartists in describing their influences. This was accomplished in two main ways: (1) through the use of preparatory wall text describing important moments in the history of agriculture, particularly around the development of corn, and (2) through the first image that viewers encountered as they entered the gallery, which was a historical installation photograph from 1936 from the Museum of Modern Art.

The exhibit text situated the artworks on display with suggestions of their historical precedents to fit them into a lineage of art and science works. Historical facts are marshalled to argue that biotechnology is part of a longer lineage of biological interventions. The examples hail primarily from agricultural contexts because of the museum's context within a land-grant institution, with a continuing agricultural focus, inside a research university. To set the stage for artworks that included a living corn maze, a sculpture and photography project about cattle breeding, and a piece on the gamification of genetic experimentation on *Arabidopsis thaliana* plants, the curatorial team recalled for visitors details of the history of plant and animal breeding. *Teosinte to Tomorrow*, a corn maze by Molly Renda and William Dodge, was installed at NCMA's Ann and Jim Goodnight Museum Park and was available via virtual-reality headset at the Gregg Museum of Art & Design. The maze design was based on the photographs and drawings of Josef Albers created during the years in which he and Anni Albers traveled extensively in Mexico (1930–1960). Deep in the center of the maze, visitors encountered a plot of teosinte, so that the maze was also a time machine, taking visitors back from today's conventional corn to its ancestral genetics. This historical context particularly highlighted maize because of its relationship to Renda and Dodge's artwork: "Biological and aesthetic selection have always been intertwined. Genetic archeologists have shown that ten thousand years ago, teosinte, the genetic predecessor to maize, was already under cultivation in what is now Mexico" (Carroll 2010).

Equally important for setting the historical stage was the first image that visitors encountered on entering the gallery. For whatever arguments that we might make about their aesthetic value, few of these breeding programs have been positioned as works of art. It was equally important in the context of the show to suggest the way in which artists have long been present in the context of developments in genetics. The exhibition textually posed the history of breeding for aesthetic purposes as an artisanal and art-related practice, but the primary material link was presented in the form of an installation photograph of the painter, photographer, and delphinium breeder Edward Steichen (1879–1973), just inside the entrance to the gallery (figure 6.4). To find the roots of contemporary art and genetics, however, the text noted, we need only look as far as Steichen.



Digital Image © 2002 MoMA, N.Y.

6.4 Edward Steichen (1879–1973). © Artist Rights Society, NY. Installation view of the exhibition, Edward Steichen's *Delphiniums*. The Museum of Modern Art, New York, June 24, 1936 through July 1, 1936. *Source:* Photograph by Edward Steichen. (IN50.2) The Museum of Modern Art Digital Image © The Museum of Modern Art/Licensed by SCALA/Art Resource, NY.

In 1936, Steichen installed the first live plants in the galleries at New York's Museum of Modern Art and later served as the museum's Director of the Department of Photography from 1947 to 1961 (Hartmann 2019). Steichen was an avid plant breeder whose massive delphinium inflorescence drew crowds. Steichen used careful plant breeding techniques over more than 25 years to achieve these delphiniums. He would continue this project in the years to come, turning to direct genetic interventions, including the use of the medication colchicine, which created mutations in the plants, and therefore new varieties.[10] These direct genetic interventions are often pointed to by bioartists as they situate their work in a dual lineage of art and science. Just two years after the 1936 exhibition, Steichen retired from commercial photography to create more time to pursue his delphiniums. His *Connecticut Yankee*, named for Mark Twain's novel *A Connecticut Yankee in King Arthur's Court*, was brought to market in 1965 and remains available to the present day (Gedrim 1993).

In the context of the *Art's Work in the Age of Biotechnology* exhibition, the presentation of the text on Steichen and the exhibition image were meant to signal to viewers that however novel bioart and biodesign might seem to the public outside the art world, the history of artists working with biotechnology extends back to the development of modern genetic intervention techniques. Bioartists frequently point to Steichen as an influence and an early example of an artist directly intervening in the genome of a living thing for an artistic purpose. Therefore, placing an image of Steichen's installation at the entrance to the exhibition facilitates the history that many bioartists would like to tell about themselves. Steichen's work is also remarkable because of its timing. The art book associated with the exhibition further expounded on the context in which Steichen experimented with delphinium breeding by bringing in the voices of other scholars on the subject of tools and techniques used in industrial and home experimentation in developing new plant breeds. As historian Helen Curry (2016) writes, the mid-1930s marked the beginning of what would turn out to be a period of considerable scientific interest in creating new cultivars through genetic interventions involving a variety of poisons, X-rays, and radioactive substances. These mutation-making practices would continue through the early 1950s as scientists, farmers, and home gardeners sought to see what new possibilities that atomic science might bring to their botanicals. Tiago Saraiva (2016) has shown the relationship between ideologies, particularly in fascist Germany, Italy, and Portugal, and breeding regimens associated with agricultural production. Such values, be they democratic—as in the case of spreading access to the plant breeding technologies in hopes of creating experimentation in homes and farms across the country—or fascist—such as breeding pigs for the most efficient use of national feed stocks—the politics of these regimes are embodied by the resulting changes to the genomes of living things. It is often suggested that the recent developments in genomics, such as at-home DNA testing for people and even for our furry pets, are a new degree of availability of biotechnology. A look back at this period of amateur or citizen science experimentation with plant breeding, however, reveals that the story of nonscientists working with what we now think of as biotechnology has a long, rich history. Understanding the history of genetics can help enrich our interpretations of artworks in regard to these technologies. Steichen's interest and work show that rather than following scientific advances and celebrating and making use of them in due measure, artists are often at the vanguard of conversations about science, particularly genetics.

INFLUENCES AND INSPIRATIONS: BIOART, TACTICAL MEDIA, AND SPECULATIVE DESIGN

Much of the work in the area of art-science, and perhaps particularly in the area of art and emerging technoscience, is situated as a new development. In fact, a great deal of work has taken place in this area. Although it is important to recognize new artworks and streams of thought in art, emphasizing their novelty tends to remove them from their context and, as a consequence, mutes some interesting interpretations of the work. The artists represented in *Art's Work in the Age of Biotechnology* draw on a number of artistic and design traditions to produce their work. In various measures, many of the artists have engaged with bioart, worked with performative interventions, or produced projects influenced by speculative design. Prominent among the many types of artworks that have engaged genetics in the past twenty-five years has been the practice of bioart, or art that involves working with living things including tissues, bacteria, organisms, and life processes.

Although there is limited space in wall text and exhibition guides, it was an important part of the team's agenda to make clear that art-science work is not a novel idea but a form of engagement with the sciences that spans many scientific disciplines and issues. It was important to draw works for the exhibition from many quarters of art-science work and to highlight their contrasts and similarities by positioning them in contrasting visual and physical relationships in the gallery and through their related wall texts. The first strand of work that the exhibition attempted to highlight was bioart and the studio-labs that such artists have built to conduct their work. Though not directly emphasized in the text, the team also sought to highlight the relationship that many of these artists have had to DIY biocommunities and to open access laboratories. The exhibition noted that the term *bioart* was coined by Eduardo Kac in 1997 in relation to his artwork *Time Capsule*, though many artists such as Joe Davis and Suzanne Anker, who were featured in the exhibition, already constituted a community who had been working in this area for a decade. A marked feature of the last three decades of bioart work has been the emergence of artistic laboratory spaces, which afford artists the opportunity to work in biological labs and enable new artworks. Such spaces are the site of both physical laboratory resources and practical protocol know-how. They include the UWA's SymbioticA (2000), led by Oron Catts (detailed in Chapter 4); Rensselaer Polytechnic Institute's BioArt Initiative (2007), founded by Kathy High, with Rich Pell, Daniela Kostova, and Boryana Rossa; the University of Windsor's Incubator, founded by Jennifer Willet (2009); Brooklyn-based Genspace (2010), which sponsors the Biodesign Challenge for which *Kerasynth* was developed; the School of Visual Arts' (SVA) Bio Art Lab in New York (2011), established by Suzanne Anker; and the University at Buffalo's Coalesce (2016), initiated and directed by Paul Vanouse.

Kira O'Reilly, another former SymbiotcA resident led an MA pilot program in Ecology and Contemporary Performance at Theatre Academy of the University of the Arts Helsinki. Also influential in providing field experiences for artists in northern Finland is the Finnish Bioart Society, led by Erich Berger. In addition to supporting artist residencies and exchanges, the group maintains a gallery space, SOLU, in Helsinki.

It is notable that many artists represented in this exhibition have founded, trained in, or contributed to these growing institutions. Paul Vanouse was an early SymbioticA resident who went on to found Coalesce. Joel Ong received a Master of Science degree at SymbioticA and held a residency at Coalesce. Heather Dewey-Hagborg performed the DNA analysis for *Stranger Visions* at the early Genspace lab, and Genspace sponsored the biodesign challenge that occasioned the creation of *Kerasynth* (Diana Eusbio, Erin Kirchner, Grace Kwon, Rachel Rusk, and Sydney Sieh-Takata). Suzanne Anker's Bio Art Lab at SVA was the location for the 2017 Biodesign Challenge student exhibit.

Another institution that has helped launch art and design projects on biotechnological subjects is associated with the iGem (International Genetically Engineered Machine) competition. Designers Alexandra Daisy Ginsberg and James King worked with the Cambridge University undergraduate iGem team that produced *E. chromi* (2009), a bacterium genetically engineered to secrete a variety of colored pigments using BioBricks that they inserted into *Escherichia coli* bacteria. The designers sought to complicate the possible futures that *E.chromi* might bring about by creating *The Scatalog*, which posited a use for the engineered bacteria in disease detection and materialized the project as a speculative briefcase of brightly colored stool to raise questions about the possible results of synthetic biology. Another iGem-related artwork was *The Pink Chicken Project* (2016), the work of Swedish biodesigners Linnea Våglund and Leo Fidjeland. This online media campaign used many of the hallmarks of tactical media to propose "using a 'Gene Drive' to change the color of the entire species *Gallus gallus domesticus* to pink" in the interest of creating a pink Anthropocene geological marker. Together these labs form a latticework of resources, technical expertise, social networks, and shared research interests that formed the field of bioart.

In *Art's Work in the Age of Biotechnology*, a number of pieces make use of possibilities brought forward by tactical media practitioners. The concept of the company, with its strengths and potential concerns, is something that artists enroll for their own purposes. Siren Genomics offers a booth where visitors can learn more about the company's research toward creating mermaids by manipulating hox genes. Even as *Siren Genomics* raises questions about the role of biotech companies, and as Kirsten Stolle's *Miracle Grow* reminds us of a history of problems produced by capitalistic interventions in agriculture and food systems, some exciting aesthetic projects such as *Kerasynth* are precursors to companies created from art world ideas. These similarities and contradictions offer an opportunity to reflect on the power dynamics of corporate biotechnology and the roles that corporations and individuals are playing in our genetic futures.

Other pieces in the exhibition, such as Emilia Tikka's film and object *Eudaimonia: The Biotechnization of the Soul?* hail from speculative design. They offer not just the objects for an imagined future, in this case injectors with personality-related gene-editing technology, but also well-developed scenarios about how, why, and by whom those objects might be used. This form of design shows us new technologies in our own society's hands, rather than a utopian future where people face choices made easier by technology or are themselves better people such that the choices are made clearer. Tikka's film gives us people very much like ourselves facing a radical new technology. Speculative or critical design was developed by designers Anthony Dunne and Fiona Raby at the Royal College of Art's Design Interactions program (Dunne and Raby 2013). Many people are accustomed to thinking about design from a modernist perspective, that is, understanding design primarily as a problem-solving tool. Dunne and Raby, however, propose speculative design as an activity that imagines the world differently by envisioning possible scenarios and investigating them through methods such as designing artifacts for that scenario or researching potential users' reactions to a created situation (Dunne and Raby 2001).

Rather than seeking to solve an already given problem, speculative designers consider the role of designers without the notion that each problem has a best design solution, which usually is translated to be a new or improved product. Instead, speculative designers have moved away from the designer's service position, in which their profession works to fill in gaps or problems with designs. This way of thinking resituates the designer and offers the possibility of new types of interactions with other professionals in a multidisciplinary peer capacity rather than as a consultant or in a troubleshooting role. This tendency toward collaborative scenario creation may account for the highly interdisciplinary work that has resulted from the use of this method.

Like Tikka's exploration of future home-use gene-editing technology, which has roots in discoveries involving genetics and personality, *Kerasynth* offers a future in which a wool fiber that does not require sheep brings massive changes to the fashion industry. The 2018 Biodesign

Challenge team, *Kerasynth* offered a future scenario in the tradition of speculative design. In this future, the team imagines that the technical problems with lab-grown wool are overcome and the product becomes a fashion “must.” Artifacts including fashion shoot images, a production process film, and prototyped clothing helped the designers explore the possibilities for what this change to the industry would mean. There are many more influences and traditions displayed across *Art’s Work in the Age of Biotechnology,* and attention to the interplay of these strands can help us situate art about genetics in the lineage of art history to which it belongs.

SCIENTIFIC COLLABORATORS: SCIENTISTS SUPPORTING ART-SCIENCE WORK

Many artists who produced work for the show have scientific collaborators who provide background or technical information, resources such as lab materials and equipment, and access for artists in the form of vouching for the artist’s work with references or simply adding their name to a project to lend it further scientific credibility. Some artists want to extend conversations with scientists about the technical aspects of their work and its social implications through material means, whereas others seek to draw audiences into aesthetic, emotional, and philosophical experiences. How these collaborators are treated in relationship to their artistic counterparts is a practical and philosophical problem for curators. The question of credit goes to the heart of the hierarchical issues at stake in positing work as art or science. Curators of such work deal with crediting these collaborations in a variety of ways, from treating scientists as artistic collaborators to seeing them as technicians, not dissimilar from the team that might execute a modern sculpture design. This variability can lead to complications for the exhibition’s institution and for the artist and scientist’s relationship. The variability of those relationships and how public the scientist wishes to be, and how public the artists wishes to have the scientist be, means that unless the teams are assembled by a facilitator connected with the exhibition, the common practice is to try as much as possible to relate to the artist’s collaborators on the artist’s terms. In the case of the exhibition at hand, this meant listing scientist collaborators according to the way in which the artists reported them. Like the order of authors in a scientific paper, which reflects different kinds of contributions to the research program and publication output, these relations are reflected in what might seem to be tiny changes to wall texts, but, in fact, these choices are of great gravity in the art world because they indicate involvement in conceptualization versus execution. For example, in this exhibition, Paul Vanouse (specifically his scientific assistant) in the wall text credits his lab manager at the University at Buffalo's Coalesce: "Scientific collaborator: Solon Morse." In other cases where the collaborator has helped to develop the project artwork itself, scientists are listed in the same manner as artists.

These wall text additions situate the works in the landscape of art-science for audiences who may not be aware that many of the artworks in the area of art and biotechnology have been created in consultation with scientists. In the same way in which scientists make use of graphic and image expertise in their work, many artists make use of scientific materials and ideas. The artists in this exhibition who are engaged with biotechnology, however, take this a step further by working with scientists in a range of ways. Sometimes a scientist's work is an inspiration or even a muse for an artist; other scientists provide resources or technical information on an individual basis. Yet other projects are the result of partnerships between artists and scientists who work together in a collaborative manner. This is the case for artist and scientist teams who are involved in ongoing relationships, such as the creative team of evolutionary ecologist and artist Aaron Ellison and architect and multidisciplinary artist David Buckley Borden, who presented the playful but provocative sculpture *Novel Ecosystem Generator* (2019). Both art and ecological expertise are on display as the work asks viewers to consider the ways in which human intervention is leading to the production of wholly new ecosystems as part of the ecological changes that are part and parcel of the Anthropocene.

Other works use a mixture of credits because they require scientific assistance to various degrees at different stages. Adam Zaretsky's *Errorarium* involved scientists in several ways. His piece is shaped like a video game console and has a fully contained "unpredictability" of genetically altered plants growing inside. The work raises questions about predictability in genetic expression and how we should understand the work of scientists in changing genomes and the possibilities and limitations of the resulting phenotypes. The artist's process involved discussing his ideas and learning the genetic intervention protocol from scientists by working in a lab at the University of Leiden (scientists Dr. Ir. Bert van der Zaal in collaboration with David Lourier and Neils van Tol). These scientists collaborated with Dr. Carole Saravitz at North Carolina State's Phytotron, a facility for growing plants under various combinations of strictly controlled environmental conditions, to propagate the plants for the artwork on site. In his wall credits, Zaretsky posits a more complex relationship between the collaborating scientist and the potentially collaborating visitor: "These plants were created in the lab of Bert van der Zaal (in collaboration with David Lourier and Neils van Tol), but their future genetic expression can be influenced by visitors."

Some of the collaborations between artists and scientists unfold on a longer scale and involve both the scientists and the artists working at the cutting edge toward a new project. Artist Charlotte Jarvis, creator of *In Posse*, is working in a long-term collaboration with scientists to produce female sperm. In the same way in which Steichen's experiments with delphinium mutations and TC&A's ironic *Disembodied Cuisine* (2003), the first production and consumption of laboratory meat, were created by artists at the cutting edge of what is often considered science's domain, Jarvis is in a position to realize breakthroughs in science and in art. Her collaborator, Dr. Susana M. Chuva de Sousa Lopes of the Leiden University Medical Center, received the Netherlands-based Vici five-year science grant to pursue the project of creating spermatozoa cells. Both parties are continuing their shared work, which meets their individual interests and is fitted into the separate areas of art and medicine. Charlotte Jarvis, like Paul Vanouse, lists her scientific partner in her wall texts but does not designate her as being a scientist. Rather, she lists the work as "in collaboration with Susana M. Chuva de Sousa Lopes."

These different modes of crediting and their effects, that is, how adding these credits relates to the audience's perceptions of the artist's expertise versus perceived reliance on scientists, remain open questions. For this exhibition, artists were not asked to connect their work with scientists, but the nature of the call for work about biotechnology meant that many of the selectees did have scientific collaborators whose roles needed to be considered as part of mounting the exhibition. Contemporary artworks are often the result of collaborations, so this problem is in no way unique to work made with scientists, but it does raise interesting questions about how crediting does unfold. This is particularly true when the artworks are sometimes chosen with an eye to their scientific validity or access, because this helps situate the works as ensconced in the scientific community as well as the artistic one.

ARTISTS AND BIOTECHNOLOGY: USING VERSUS CRITIQUING

As we saw in Chapter 4, for artists who use scientific means to critique biotechnology and the life sciences, there exists an essential tension between their use of biotechnical techniques and wet lab protocols and the reception of their work. In some cases, artists act as methodologists (Nelson 2020). Nelson defines methodologists as actors who reveal contingencies and uncertainties in taken-for-granted science in proposing and executing experiments that call into question established facts, methods, or premises. Curators can work to heighten and draw attention to experimental setups and their implications posed by artists by offering opportunities for artists to discuss their work and providing additional scientific contexts to audiences that orient them to the artist's methodological intervention. In the case of *Art's Work in the Age of Biotechnology*, it was necessary to construct events that allowed artists to more fully engage with audiences about the philosophical implications of their work.

One such example was *Lucky Mice* (2018). This installation and proposed protocol used a mouse-operated dice-throwing machine to answer the question: what if luck is heritable? To test this possibility, the artist proposed the idea of using a dice-casting apparatus controlled by a mouse, then selecting mice who had the best die throws and breeding them together for successive generations to create lucky mice. *Lucky Mice* was cocreated by eminent bioartist Joe Davis, multimedia artist Dana Dal Bo, and biologist Ashley Seifert as an experiment. Acceptance by the scientific community was crucial to their concept. It would have been possible to frame *Lucky Mice* as an artistic performance and thereby bypass the Institutional Review Board, but because the work's status as a form of scientific inquiry was important to the artists, the collaborative actively sought to run the protocol as an ethically approved experiment.

In a way, the experiment was a critique of the ideas that contemporary biotechnology puts forward about what is heritable; on the other hand, the piece necessarily used protocols from animal breeding practices to create the artwork. To make their point about how science treats luck and what counts as scientific research, Davis and his collaborators used scientific apparatus and protocols to analyze or expand modern understandings of genetics and heritability. The importance that the team placed on the perception that the work was not just performing a representation of science but actually doing science points to Davis's refusal to accept that art and science are entirely separate practices (Ferdin 2000). As a result of the way in which artists have wanted to participate in conversations often reserved for scientists, they have tended to use scientific materials as their mediums. This tension between using and critiquing biotechnology continues to be present in many art and science works, including a selection of pieces in *Art's Work in the Age of Biotechnology*. Many of the artworks position themselves as moments of tension between the use of biotechnology and its critique, and curators are in a position to heighten these contrasts in exhibitions. To fully realize the work, it was important to the artist to approach it in several ways: a performance of a mouse dice-throwing trial, a lecture by Davis discussing the work, and an installation of the apparatus and technical information about the statistics necessary to run the experiment, accompanied by its ethical review and a video of the trial.

Davis's work used the form of the experiment to criticize science's limitations in regard to ideas that can be proven through experimentation. Other artworks criticize technological means and their deployment in societies. In Heather Dewey-Hagborg's *Stranger Visions* (2012–2013), viewers encountered a series of portraits made possible by the artist's analysis of DNA that she had recovered from discarded items, such as hair, cigarettes, and chewing gum. The piece includes three-dimensional printed portraits, which Dewey-Hagborg produced from the DNA taken from everyday objects discarded in New York. These discarded source objects are displayed and labeled in black boxes. Yet even as these faces stare back from the wall, loaded with the suggestion of a future where privacy is fundamentally changed by the genetic information we each shed constantly, viewers are aware of the artist's choices in selecting what traits to test for and to emphasize in the portraits. The DNA analysis offers only probabilities, not certainties.

Possibility and probability surface again in the case of Joel Ong's *Terra Et Venti* (2018), which engages with synthetic biology in associative and conjectural ways. His speculative futures piece is a research-creation project that explores the role that synthetic biology may play in planetary-scale geoengineering and weather modification practices in the near future. The computational system presented in the gallery generates text for insertion into the genome of the *Pseudomonas syringae*. The bacteria, a plant pathogen, is involved in atmospheric biological ice nucleation and the formation of clouds. *P. syringae* are ubiquitous in the soil, on plants, and in the air, travel freely on planetary circulation systems, and are literally rainmakers themselves. Ong uses the bacteria as a platform for speculating about future weather manipulations and in doing so implicitly calls into question previous weather interventions such as conventional cloud seeding, which is already done with the unmodified bacteria.

Ong's piece connects with a long tradition of artists' involvement with genetics as an information code, an area pioneered by his coexhibitor Joe Davis. In the late 1980s, Davis devised a method for coding visual information into DNA. The resulting project, *Microvenus,* was created with molecular geneticist Dana Boyd at Jon Beckwith's laboratory at Harvard Medical School and at Hatch Echol's laboratory at the University of California, Berkeley. The piece used coded visual information with the intention of communicating with extraterrestrial intelligence. This included a visual icon representing the external female genitalia (the same icon as an ancient Germanic rune representing the female Earth) and a short decoding primer into a 28-mer DNA molecule. Ong's piece builds on this tradition of treating the genetic sequences as a medium for artistic expression. Both these works oscillate between cutting edge ideas in science that employ scientific tools as a medium and as a critical edge. In Davis' case, this edge was a critique of previous information left for extraterrestrial discovery by NASA scientists; in Ong's case, this is the suggestion that it might be possible for DNA-encoded poetry to rain down on us. In either case, there is a critique of how we imagine what is coded in DNA and the way in which the literal realizing of the metaphor of DNA as text is always culturally bound. In these two cases, this results in an understanding of the possible science communication and literary uses of DNA's capacity to be understood as a language code.

CATEGORIZING MATERIALS

Materials and their associations are a major way in which art and science are categorized. As we have seen across the chapters in this book, materials carry immediate contextual associations for many viewers, but their story is more complex. The interpretive flexibility of objects offers an opportunity to curators who want to position works as art or as science or to emphasize their liminal qualities. One example of this process from the exhibition was Paul Vanouse's *America Project*, which received the Ars Electronica Prix Ars Hybrid Prize in 2017. The project makes use of a relatively common genomic technology to make a point about our shared DNA. In artworks that engage science, it is often an issue of exposing the process by which knowledge is created rather than emphasizing the outcome. This is the case for the *America Project*, which like *Latent Figure Protocol* was best appreciated as both an installation and a performance. The artwork, which used single gel electrophoresis to run a mixture of DNA, consists of a spittoon into which participants offered a DNA sample by swishing a cup of saline and depositing it into the spittoon. Vanouse created specialized software that inverts the process typically used so that the artist can cut the DNA with known enzymes in specific locations to create a pattern. The fact that it is possible to use the mixture of DNA in the spittoon to create a predetermined image (for example, a flag or a crown) demonstrates that humans have much more shared DNA than differentiating sequences. Everyone's spit is mixed together, making individuation impossible. All collected samples are, as the artist puts it, "promiscuously commingled." Rather than emphasizing genetics as a marker for individuality, what is visualized in the images that Vanouse renders is our shared identity.

Art's Work in the Age of Biotechnology's programming offered lab apparatus outside the lab and, in the case of Paul Vanouse's piece, a participatory experimental protocol outside the gallery. Volunteers were offered the chance to contribute their DNA (via spit) to the collective DNA image that Vanouse produces from running a gel electrophoresis tray with a mixture of volunteers' DNA. The call to take science out of the laboratory has been heeded by many artists, but it is up to curators to ensure that the sense of access is preserved. One avenue for doing so is programming. For the program *Spit Collection for America Project by Paul Vanouse*, an oversized spittoon was set up so that students could contribute at North Carolina State's Talley Student Union, apart from either a science or an art institutional context. The spittoon certainly reads visually as technical, however. A consideration for the attending narratives and understanding of scientific equipment, which often appears in such artworks, versus an intentional unpacking or complicating of those associations is important in positioning works for exhibition.

Because STS scholars are aware that a new set of associations might be drawn for any given material assemblage, visual readings by the public in a specific context must be considered. The recognized links from labs and from nonlab contexts are important to show both artists' technical facilities with laboratory materials and the ways in which biotechnology can be accessed outside laboratory spaces and without laboratory materials. Once Vanouse's *America Project* was cleaned and installed in the Gregg Museum of Art & Design, the activity of the protocol performance itself was hidden, and the "read" of the spittoon as a sculptural context was heightened. In the lowered light of the gallery, the spittoon was set atop a 3-inch platform to elevate it and the two informational plinths about the project. The latter also contained the projectors, which illuminated the wall behind the spittoon with a filmic representation of the gel electrophoresis trays as they were running and resolving into images. In this way, Vanouse had predetermined the lab's outcome, emphasizing the predictable similarities between human DNA even as the specific participants were unknown.

Another moment for considering the relationship between materials and the situating of a work as having a laboratory or nonlaboratory response was just inside the gallery. As one walked from the front glass doors of the museum toward the gallery, *Stranger Visions* floated on the black occlusal wall, which hid the rest of the exhibition from view. Standing before the piece, tucked into the right corner, was a brief history of the relationship between art and biology illustrated by Steichen's delphinium installation image. Passing Heather Dewey-Hagborg's *Stranger Visions* on the right to enter the gallery, on the immediate left the visitor found Emeka Ikebude's *Fragments*, inviting one to think of the similarities and contrasts between these biotechnology portraits. Heather Dewey-Hagborg's *Stranger Visions* portraits and supporting lab materials pointed back at laboratory techniques. The catalogued and boxed samples and portrait outputs were shown, and the process is suggested but not displayed. With the lab equipment missing but fundamental to the project, audiences were encouraged to picture the black-boxed laboratory where unseen processes are able to render a cigarette butt into a face.[11] Indeed, the critique of this work rests on the interpreter's understanding that these processes are occurring away from public view and involve materials not seen in the exhibition. Furthermore, the three-dimensional printed portraits maintain an uncanny digitized look, which suggests their origins as computer models and gestures at the effort in the laboratory required to produce them. Together, the artists sample boxes and portraits against the clean field of a black gallery wall, which suggests the facts rendered by the order and machines of science. Yet even the location and sample information gestures at a larger and more complex world rendered simple in the laboratory environment.

Like *Stranger Visions*, Emeka Ikebude's *Fragments* (2016) plays on the concept of the portrait by suggesting multiplicity rather than singularity. Here, however, the laboratory is never invoked, and everyday materials are emphasized. The image is a portrait made from reclaimed toothpicks, which the artist dyed and arranged in bundles, but the artist's imposition of the image of a single individual belies the complications of its process. The toothpicks themselves could hardly be more ordinary and follow in the tradition of found materials, but the intense labor in dying and arranging them had heightened one's sense of their value. The discarded toothpicks each contain the DNA of its individual user. Although the individuals who used those toothpicks will never be known, the image of the discarded toothpicks that they create together raises questions about the biological information, potentially including a tiny amount of blood, tissue, and microbes that help process what we eat, which we each so easily discard. Each toothpick in this composition represents a human being as a contributor and unwitting participant in this project of rethinking the bacterial and viral genomes of the human body. In the context of the gallery, *Stranger Visions* and *Fragments* were placed across from one another, inviting viewers to consider the contrasts of these two types of portraits and the types of materials used to create them.

OBJECTS AND CONTEXTS

Context is most often understood by curators as being delivered by a combination of all text and the physical positioning of an object in the gallery space. In the case of artists engaged with science who are seeking to suggest the links between objects they create, identify, or highlight and their social uses, artists themselves sometimes offer a division between objects and contexts in an effort to relate the social meanings and cultural uses of emerging technologies, critical designs, or other objects that they have created. This was the case for the work of Charlotte Jarvis, Emilia Tikka, and Maria McKinney. A close look at the cases of these pieces as they were situated in *Art's Work in the Age of Biotechnology* is helpful in understanding the way in which curators work for and with artists to situate their projects physically and epistemically. To understand the relationships between these objects and films, an overview of the three artworks is helpful. After a brief overview of each piece, we will return to a discussion of how these works were situated to make clear the relationships between the physical objects and artist-provided filmic context.

CHARLOTTE JARVIS'S *IN POSSE*

London-based artist and researcher Charlotte Jarvis works with the body and biotechnology. This long-term research interest has resulted in a series of pieces collectively titled *Corpus*, which aim to find alternative spaces of discourse for the human body. The works in this series use stem cell research, genetic engineering, and oncological technologies to place the body, in particular the artist's body, or more precisely fragments of her body, in between states that give rise to philosophical problems. Ideas such as mutation, tumor production, and immortality give rise to technical laboratory problems, which are intimately linked with questions in

IN POSSE:
WORK-IN-PROGRESS FEMALE SPERM:
THESMOPHORIA RITUAL

6.5 Charlotte Jarvis, *In Posse: Making Female Sperm*, 2018–ongoing. *Source:* Photograph by Matthew Gay, courtesy of the Gregg Museum of Art & Design, 2020.

western philosophy. As part of this series, the artist created *In Posse*, an inquiry into the possibility of female sperm (figure 6.5).

Jarvis is collaborating with Susana Chuva de Sousa Lopes in Leiden, The Netherlands, and the Kersnikova Institute in Ljubljana, Slovenia, to place her body at the intersection of gender, sex, and reproduction. The collaborators are attempting to make semen from the artist's cells. In the laboratory at Leiden University Medical Center, they are using human induced pluripotent stem cells derived from Jarvis's skin to grow spermatozoa. Such cells are "reprogrammed" and act much as embryonic stem cells would. This includes the capacity to differentiate, and it is this possibility that makes them attractive for a project about creating female sperm. These cells have XX chromosomes, which are understood as a female genetic marker. The first step toward creating female sperm is to attempt to erase one of these X's through accelerated mutation, scanning, and selection. The second intended stage will be to use CRISPR (clustered regularly interspaced short palindromic repeats) to add synthetic genes found on the male Y chromosome. Finally, the collaborators will attempt to grow a healthy colony of these gender-mutated pluripotent stem cells and differentiate them into the sperm-producing cells like those found in testes.

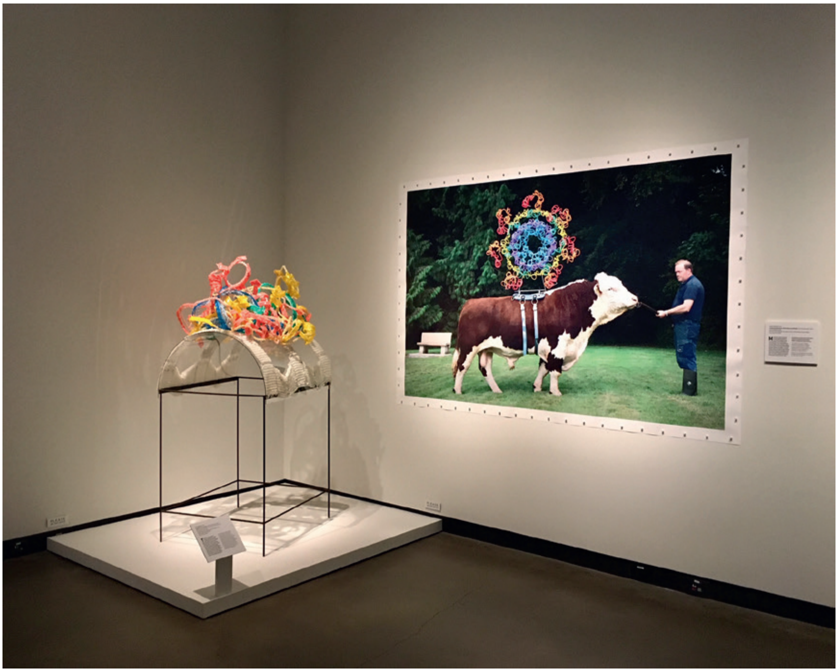
Separately, seminal plasma has been developed through the project at the Kersnikova Institute. To create this plasma, Jarvis has conducted artistic workshops with groups of women who discussed the potential for female sperm and who donated blood samples toward her efforts. Thus, the development of the biological products of this project overlap with the involvement of participants in an investigation of the festival of Thesmophoria. Jarvis's workshops and donation events are based on an ancient Greek festival that was exclusive to women and largely undocumented. Jarvis uses her own female semen as a starting point for reimagining the Thesmophoria with multiple groups of "womxn" at different sites across the world. These events are built around the few details that are available about the original festival, which included a feast, the burial of a pig, "ritual obscenity," and serpentine and phallic offerings. Together participants create new collaborative rites and rituals around the donation of blood and associated laboratory protocols involved in making the project.

Jarvis's public art practice is notable for the way in which informed consent takes place: the women are enrolled in understanding not only precisely how their cells will be used but also the contexts, goals, and potential of this project. Those who offer fragments of their bodies to the workshop also have an opportunity to shape conversations about the use of this future technology and reflect on current issues related to gender and reproduction. The base of the seminal plasma developed at the Kersnikova Institute is extracted from the blood of multiple womxn, a group which the artist refers to as a coven. Thus, Jarvis configures making the seminal fluid a collective act and a symbolic rejection of patriarchal hierarchy.

The title of the work, *In Posse*, is a Latin term with a literal meaning of ″before we are born." Jarvis chose this title because it refers to something that is possible, that has potential, but is yet to be called into existence. As Jarvis puts it, "*In Posse* is striving for a form of technological, biological and creative activism. *In Posse* seeks to use science and art to undermine traditional notions of patriarchal power and to examine the meaning of gender now and in the future." Jarvis's work could be interpreted as the cutting edge of reproductive science and fertility medicine, or it could be understood as taking a lab technique out of its original context and repurposing it with new goals. This has the effect of exposing scientific processes and their goals to public scrutiny and inviting speculation about how alternative sets of actors might direct these processes in new ways.

MARIA MCKINNEY'S *SIRE*

Maria McKinney's long-term project involving bulls (*Sire*, 2018) situated itself in relation to art and agriculture using a rhetorical resource discussed earlier: the history of genetic interventions, in this case animal breeding (figure 6.6). The artist invokes pre-Christian Europe and observes that people annually performed customs in relation to the reaping and sowing of the harvest, which have since been popularly interpreted as an attempt



6.6 Maria McKinney, installation view. On the left are myostatin semen straws, wire, and fixings, 80 × 65 × 70 cm approximately, 2016. On the right is an archival pigment print of *Longevity/Apoptosome on a Black Water Lad* (HE2067), 125 × 225 cm exhibition copy, 2016. *Source:* Installation photograph by Matthew Gay, courtesy of the Gregg Museum of Art & Design, 2020.

to influence the future behavior of nature. Part of this practice involved making a corn dolly as a symbol of the fertility of the land and living things. This traditional craft practice inspired McKinney's weaving of bovine semen straws into wearable sculptures, which she installed on the backs of sires. She contrasts this practice of attempting to control fertility with modern genomic practices. According to McKinney, "Genomics has given humans the ability to truly influence how nature behaves in future generations of animal and plant species."

To realize the work, McKinney collaborated with Dovea Genetics, a bull stud farm with ninety bulls standing at stud, producing semen in a controlled environment. Scientists and veterans involved in the project include quantitative geneticist Donagh Berry (Teagasc), genome biologist David MacHugh, and veterinarian Michael Doherty (the latter two of University College Dublin). McKinney particularly notes that she worked with the animals' handlers to ensure that the animals were not mistreated or unduly stressed while creating the work. McKinney places special emphasis on the care of animals as integral to her work because, as she explains, "All my grandparents were farmers; I grew up in the countryside surrounded by farms and helped neighbors herd sheep and cattle into the field." This appeal to the concept of inherited and observed skills or craft ability harkens back to the idea that the Blaschkas were capable glass artisans because the craft was passed down through their family.

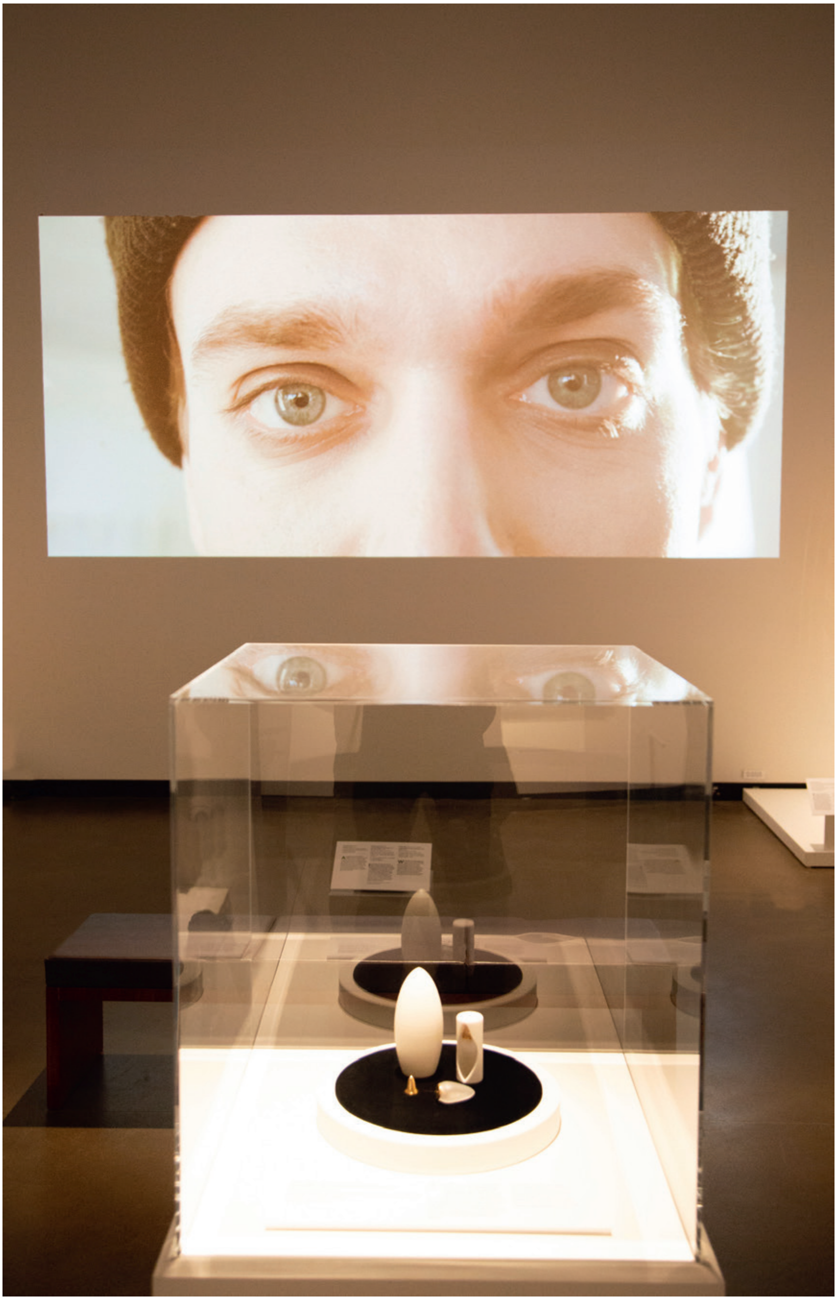
McKinney's wearable sculptures are displayed alone and depicted in still photographs. In the photographs, the sculpture and the animal are for viewers a single assemblage, yet one that promotes the tension of the origins of both. The sculpture makes visible the human interventions in the animal's body. However much we might identify the semen straw sculpture as the human addition in the image, the less visible but recognizable interventions into the animals' physiology via generations of breeding and direct genetic interventions are equally present. McKinney has also produced a film that allows us to see the movement of the animals as changed by these breeding practices and heightened by the wearable sculptures. The video installation depicts a Belgian Blue bull wearing a semen-straw object based on the myostatin gene, which controls muscle growth regulation. Through 150 years of linebreeding, Belgian farmers managed to manipulate this gene to achieve the "double muscle" Belgian Blue without modern genomic techniques.

EMILIA TIKKA'S *EUDAIMONIA*

Emilia Tikka's work *Eudaimonia* was described in some detail previously, so here I will simply refresh the relationship between her design practice and user scenarios as outlined in her film. Tikka's practice began by envisioning a genome-editing device, which was shown in the gallery, as a desirable consumer product, and its colors and display evoke the idea of jewelry—a luxurious augmentation that is seductive in form. Three-dimensional printed brass and a gold-plated needles are structured by means of frosted white glass. The imaginary product as shown in the gallery consisted of packaging, the case, and the genome-editing device made of hand-blown glass. Tikka's physical object is the result of the work to create a philosophical-speculative future scenario in which the human psyche and character have become a matter of molecular biology and can be altered with personalized genome-editing devices (figure 6.7). In Tikka's imagined future, based on claims made by some scientists about the relationship between genetics and behavior, it is believed that specific genes fundamentally determine human behavior. Explicit features of character and psychological qualities, such as empathy and creativity, are thought to be traceable to a single allele of a gene. This situation leads to the artist's speculation about the potential "optimization" of the human psyche and the possibility of building genomic mental health medicine from the context of contemporary western societies, attempting to seek what is understood as psychological optimization through neuroenhancers and mood-elevating drugs. The work attempts to raise questions about the individual and social impacts of the genome-editing technology CRISPR through a critical near-future scenario. The work is realized as both the injector object and the narrative scenario of the film, in which three individuals seek help from gene-editing technology in their quest to find happiness in a contemporary western capitalistic world.

INSTALLING OBJECTS AND THEIR CONTEXTS

To return to these artworks' components as materials for the Art's Work in the Age of Biotechnology exhibition, each piece had involved an object and a film. Jarvis's *In Posse: Making Female Sperm* piece included a physical installation of a hand-painted plastic pig head in sand to reference



6.7 Emilia Tikka, *Eudamonia: Biotechnologization Of The Soul?* 2018. Glasswork by Wiebke Matthes, Technical University Berlin. *Source:* Photograph by Matthew Gay, courtesy of the Gregg Museum of Art & Design, 2020.

the Thesmophoria festival, accompanied by an altar that held an early stage of her sperm research in a petri dish. The lab and Thesmophoria festival materials were contextualized through the film of her process and investigation of the Thesmophoria festival. Emilia Tikka offered her film *Eudaimonia* with an accompanying speculative injector object that is used in the film to edit genes linked to the human psyche. The object inspired the film, which provides a social context for the object and shows how its potential affects the lives of its central characters, which the artist describes as a dark poetic story of three individuals seeking help from mysterious gene-editing technology in their quest to find happiness in a contemporary western capitalistic world. McKinney represented her longtime project *Sire* through a sculpture, a photograph, and a film. Her semen straw sculpture was based both on the myostatin gene and on folk-weaving traditions of making corn dollies. It was backed by an image of another sculpture from the series in situ on the back of a bull and her film *Double Muscle* (2016), which features a Belgian Blue bull harnessed to the myostatin gene sculpture.

The objects appealed in some sense to the authenticity of the artistic research efforts involved in these works, including lab work toward female sperm, an embodied injector object, and a woven semen straw sculpture, along with a film that could be posed as offering further context. Although the affordance of film surely lent itself to this context-making, it should be noted that many other materials might have been employed in a similar fashion. To say that these projects with their attending materials presented a puzzle for the curator would be incorrect, because these pieces were, of course, selected so that this resonance between how their works could be installed and interpreted preceded their selection. Once the objects are selected and the gallery design is under way, it is necessary to use the resources at the curator's disposal, namely descriptions of the artworks and their creators and the visual and physical impact of locating the objects in space to relate the artist's intentions while also making sense of themes of the show. In this case, each artist had offered an art object, along with a film that further contextualized the object. It is important to note that these artists did not understand their objects to be props or artifacts left over from the production of their films. Instead, the materials from each of the physical installations appear in the films so that the artists can further contextualize their use and, therefore, meanings. The objects and the films were separate though related methods of the investigative aspects of their projects. The tension between the energy and specific interpretation of the use of the object in the film and the materiality of the objects themselves situates these works as representing the authenticity of the object as a presence in the gallery.

Preserving the essential tension between the physical objects and their contextualizing film was important to fully realizing the efforts of the artists and allowing viewers to perceive at least a hint of the breadth of these works in the gallery. In designing the layout and wall texts for the Gregg Museum of Art & Design, the curatorial team aimed at two goals simultaneously. We looked to preserve the viewers' sense of the objects as separated from and in some ways exceeding the films and, therefore, not reducible to the status of props or relics documenting some past event. At the same time, we wanted to make clear the films' importance as offering contexts for the objects. In the case of Jarvis's film, this meant physical and disciplinary contexts of the lab and the aesthetic spaces of the Thermophia festival fire and the ocean. For Tikka's *Eudaimonia,* the contexts were the narratives of speculative users of the genomic injector in personal, political, health institution, and social contexts. In the case of McKinney's *Double Muscle*, audiences see the actual body of the bull as affected by heritage breeding and the movement of the animal wearing the sculpture, making further visible those genetic changes.

To place these films in the conversation and to suggest the relationship between the objects and the films, a large projection that covered one full gallery wall looped a succession of the films. In focal range on the floor was placed a bench with headphones. The objects were arranged in an arc around the screen. If the viewer was seated on the bench, in the left-hand corner of the projection was Jarvis's work platformed as an altar. Spotlit on a plinth mounted near the center of the platform were Jarvis's processed materials from her participant donors. These tubes held iterations of the lab-created steps toward seminal plasma and were accompanied by a drop of the pinkish fluid, an early stage of creating the sperm itself in a petri dish. Below, on the platform, a pile of sand covered a hand-painted life-sized plastic pig's head, suggesting the sacrifices of the Thesmophoria festival and resonating with the color and environment presented in the film being projected across the wall behind the assemblage. The altar staging suggested the nature of ritual objects in sacred contexts and how this translates to the techniques and protocols in the space of the science laboratory, with a particular emphasis on the shared notion of sacrifice in both settings.

To the right of the projection, in the opposite corner, was a second platform on which McKinney's multicolored sculpture perched on a specially made stand, which gave viewers the sense of how the piece might lie across the back of a bull. The projection wall looped images of the animal wearing this particular sculpture, whereas the adjacent corner wall contained a large print from the *Sire* series, *Longevity/Apoptosome, Black Water Lad* (2016). It shows a different bull wearing another sculpture to help viewers understand that the project involved many animals and different sculptures of genetic subjects. Finally, behind the bench that faced the projection, visitors were invited to look closely at Tikka's genomic injector object. To sit down on the bench in front of the projection, visitors are likely to pass closely by the case. Although a close inspection of all the artworks is encouraged and needed to appreciate McKinney's weaving and the partially sand-covered pig's head, the platforms under the two pieces in the corners of the gallery keep some distance between visitors. In the first instance, this is to ensure the protection of the artwork, but it also encourages mystery around the products of Jarvis's experiments. McKinney's arrangement further encourages a view from a further distance to appreciate the scale of the sculpture built for a large bull by means of the *Longevity/Apoptosome, Black Water Lad* photograph, which was produced at a relatively large scale (125 × 225 cm) so that it is best viewed at a distance. In contrast, Tikka's piece was arranged to encourage close examination. The piece was displayed on a black velvet circle inside a plinthed case, suggesting the luxury or even jewelry-like aesthetics of this biotechnological medical device design. Without its film context, the piece has the potential to suggest the smooth styling of a commercial medical device. Yet like all of the pieces mentioned here, both the film and the object carried traces of materials and ideas that audiences might easily associate with either art or science. Without their related films, gallery context, and wall texts, Tikka's object might appear to belong on a sales floor. If only the trappings of the Thesmophoria festival were shown without the laboratory materials, it would be easy for visitors to miss the extensive efforts that the artist and her collaborator have undertaken in the lab to take the first steps toward female sperm. If visitors were to see the semen straw sculpture out of context, imagining a bull wearing it or understanding the significance of the scientific material it was made of would become difficult. Artists and curators work in tandem to realize the artistic visions and to place the artworks in the environment of the gallery. Curators further work to make arguments with the available artworks and to place them into conversation with one another for visitors. Together these pieces comprised the back quarter of the main gallery for *Art's Work in the Age of Biotechnology at the Gregg Museum of Art & Design* and were arranged both to give audiences the individual impacts of the objects and to suggest the relationship between these objects and their filmic contexts.

CONCLUSION

To understand the categories of art and science, the role of those who position works but are not the creators of those works requires further consideration. This process is well understood in examples of developments in science and technology, for which those responsible for positioning a work in the public sphere are often not the persons who discovered or developed the innovation. The role of curators and facilitators on the art side can help us better understand the correspondences between these two categories and to identify the ways in which actors can position projects in relation to these knowledge communities. The efforts of the curatorial team and artists, along with their scientific collaborators, for the *Art's Work in the Age of Biotechnology* exhibition challenge us to examine what might seem to be the discrete boundary between art and science with boundary-crossing works. Practices such as emphasizing the history of art and the history of science in relationship to the works, identifying and crediting scientific collaborators, and physically positioning works in relation to one another are ways in which art-science curators are able to make arguments in the gallery. As these works collectively show, the categories of art and science are determined not by universal axioms or through practices that circumscribe bodies of knowledge. Their meanings are shaped by the conversations that the pieces participate in and interpretations of the works. The artworks in this exhibition and others like them expand conversations about how art and science—in this case genetic engineering and biotechnology—are shaped by the work of artists, scientists, curators, and the public. This exhibition aims to provoke visitors to think about their power in relationship to genetics and how nonscientists can shape debates and intervene in the social and technical processes around biotechnological developments. It relies on audiences interpreting the works in such a way that they see both the art and science aspects of the projects. To accomplish this, curators, in this case the author, marshal textual and physical resources around projects to situate them as important in both artistic and scientific circles. Many of these resources are embodied by the artists in their own efforts to position the work, and others are introduced by curators as they are revealed by placing different projects in relation to each other.

CONCLUSION: ART, SCIENCE, AND TECHNOLOGY STUDIES

The politics of knowledge categorization reveal that the zoning of knowledge as art or as science is not a stable proposition. Categorizing knowledge involves constant maintenance. Actors marshal resources in service of showing how objects, people, and ideas fit into the communities of art and science. As soon as contexts change or definitions shift even slightly, liminal objects can slip out of a category or people can come to be understood as outside a knowledge community. At the same time, actors are willing to participate in and coproduce these categorizations because of the recognition and access to resources that belonging in a knowledge community can provide. In turn, efforts to situate items as art or as science can give STS scholars an opportunity to compare how knowledge categories are constructed. Aesthetic knowledge can become points of comparison for ASTS scholars, whether they hail from science and technology or from art. The practical effect is a better understanding of knowledge systems by STS scholars and practitioners working with art and science. Embracing a constructivist position helps show that the strength of the knowledge claims and the relative power of art and science are more related to context than to the specific practices by each group or the internal processes of knowledge certification within the two knowledge communities.

The frontiers of art and science as knowledge-making communities have yet to be fully probed by STS. This book indicates some of the multiple conceptual and programmatic affinities between some artistic communities and STS. If STS scholars are unable to open to our interests in art, much will remain unknown. Artists whose practices are different but whose concerns are aligned with ours will remain outside the STS tent when much might be gained through our interactions. The number of curators, facilitators, and collaborators who work with such artists who have STS backgrounds reveals something about their potential value inside STS. Their methodologies do not simply align with STS but are often drawn directly from it. If art continues to be excluded from STS, or is included only as a form of outreach, what we might learn from these artworks and artistic practices will remain black boxed. In its most obvious and closely aligned form, STS scholars should pay more attention to art's development of techniques that are appropriated by science communities. Much as historians of art have sought to consider the technical means by which mediums of art were created, STS scholars must do more to understand the history of the visual, aural, and rhetorical traditions that have hailed from the arts and that make up the evidence in the scientific community. And yet this too is not enough. Scholars of STS should consider the possibility that there are important observations about knowledge systems to be made from vantage points other than the classical ontologies, social relations, and institutions of science, technology, and engineering. The cases in this book provided a basis for a reflexive program of excavating the ways in which art and science ideas are intertwined in STS work. They serve as a call to consider new methods and forms of practice and to take STS to its logical conclusion: to treat all types of knowledge claims as social processes and insist that contexts really do count, even when it comes to defining our own subject. If the STS community heeds this call, it may find that its work has been rooted as much in the realm of constructed art as in the realm of constructed science. Closer examination of these affinities may reveal that the tools used to construct these knowledge forms share more than we might have guessed.

In short, STS has as much to offer art as it does science, and much to add to its own conceptual toolkit by comparing the two. Intervening with the tools of STS, it is possible to offer some reconciliation between the embattled positions of the rational and the nonrational. In STS, modes of production-knowledge need not necessarily be based on recognizably scientific principles to warrant attention and analysis. Concepts of rationality and objectivity can be given histories, presenting an opening to study art, artists, and artistic practice using STS tools. This book has suggested that many of the ways of encountering scientists, engineers, and other knowledge producers in STS, including ethnographies, interviews, and archival research, are equally useful in understanding the knowledge-making practices at the border of art and science. Less commonly used methods derived from visual studies, art history, and curatorial practice also add value to this endeavor and should be considered essential in the development of the species of STS inquiry devoted to art: ASTS.

Understanding aesthetic knowledge serves to enrich STS by contributing to the theory of science and technology practice. ASTS helps problematize science more fully and deepens understanding of social construction by emphasizing that the major differences between art and science relate to their social standing and relative power as institutionalized knowledge communities. The position of ASTS that both categories are equally socially constructed advances the social constructivist project and strikes a blow against residual realism in STS circles. It acts as a corrective to the tendency in STS to create differences between science and technology and to tailor different analytical approaches to these social entities. ASTS suggests a wider world of knowledge communities that can be grasped if science is no longer treated as a uniquely special form of knowledge.

This book has argued for the role of STS in the analysis of the art-science phenomenon, particularly with regard to understanding the knowledge categories of art and science. This position allows analysts to see art and science as actors' categories marshalled around resources rather than as stable decontextualized practices. We have seen that methods can be devised to examine science and art that are neither inimical nor minimizing of either knowledge community. STS's concepts of symmetry and treatment of knowledge communities can be useful in developing such methods. Indeed, whether scientists or artists like it or not, institutional changes are bringing issues of symmetry, particularly around research, to the fore. For example, one recent challenge is the emergence of the research PhD over the Master of Fine Arts (MFA) as the practice and teaching credential expected of artists. This new education hurdle creates an academic gap between more established artists and those who are newer to the field. At the same time, many in the art world complain that additional years of schooling translate into fewer years of individual practice. Artists are being institutionalized in new ways. Just as the professionalization of science in the nineteenth century had profound consequences for the practice of science, so too will art be shaped by this more extensively trained professional class. As the research PhD crystallizes as the currency of education in art, new questions are increasingly being asked about the role of art in research and the role of institutions as supporters and targets of artistic critique.

Another recent development relating to modes of entry for artists into institutions previously understood as made by and for scientists is the interaction between artists and Institutional Review Boards (IRBs) around definitions of research ethics in the arts. A number of artists have begun to seek the formal approval of IRBs, particularly in instances where universities' laboratories or resources are in use, such as with SymbioticA and Coalesce, and such approvals are required. Some artists, such as Jennifer Gradecki (*IRB# G10-02-066-01* 2010) and Adam Zaretsky (Doyle 2016), have critiqued the trend of science institutions' regulations extending control to art-making. Other challenges to science regulation have come from artists such as Joe Davis, Dan Dal Bo, and Ashley Seifert. In *Lucky Mice* (2018-ongoing), the artists worked with scientists in seeking IRB approval for an experiment on the heritability of luck in laboratory mice, a process central to the documentation and presentation of the artwork. More interventions of this type are sure to follow. At the same time, artworks and artistic modes have been increasingly placed in conversation with research frameworks responsible to the European Union. These frameworks seek to promote creativity and opportunities for science and innovation that are socially desirable and undertaken in the public interest. Such frameworks may involve public participation and feedback through forums or other informal science deliberation methods or may involve reflection on the part of scientists and innovators (Voarino 2019). For example, *Crossing Kingdoms* (2018) was an artist-led effort to consider the ways in which taxonomic kingdoms are violated and complicated by modern biotechnological practice, particularly in synthetic biology.[1] In this project, SymbioticA's Ionat Zurr, Oron Catts, and Tarsh Bates worked with Jane Calvert's engineering life research group and synthetic biologists at the University of Edinburgh in considering how artist-led research might look.[2] They created an experiment involving the philosophy of fusion, exploring fusion in the sense that synthetic biology understands it (as the clustering of cells from different species) and in the broader sense of interdisciplinary collaboration. The group understood its work as a way to facilitate reflexive thinking and the entry of new modes of inquiry into the responsible research framework with a view to enhancing process efficacy (Szymanski et al. 2020).[3]

Besides overlapping with persistent concerns in the STS community, contemporary art-science addresses broader intellectual trends in both art and science. Many of the earliest bioart pieces resisted potential enrollment in the commercialization of life or critiqued the influx of funding and resources to biotech companies in the 1990s. Second-wave bioart emphasized the role of the nonhuman and featured works around animals and microbes, particularly those functioning as part of the systems of the human body. Other projects positioned new life forms as art in work enabled by the latest techniques in synthetic biology and were often framed in ironical and satirical ways, key elements of the traditional critical toolkit of the bioart movement. Bioartists continue to focus on concepts such as genohype and genetic privacy issues, but they also take on subjects that might not seem immediately related to art as biological process. New artworks are as likely to take aim at issues of climate change, labor, and gender, even as the more traditional interests in fragmented bodies, the semiliving, and animals persist (Catts and Zurr 2002).

Whether the case in question appears planted firmly in the category of art or science or whether it is a case of liminality, rhetoric and materials that invoke ideas are constantly being reconfigured. These new configurations are designed to achieve actors' political, aesthetic, and knowledge-making goals. These goals often involve actors working to make their creative products "count" as art or science, and comparing cases reveals different goals and methods for positioning work. It is the activity of the actors in positioning works that should receive our attention here. The engagements of individual artists with the categories of art and science are idiosyncratic, but the efforts of artists to position themselves in terms of these categories have similarities. The Blaschkas literally contributed materially to science. Their models were vital cutting-edge heuristic apparatuses for understanding organisms. For them, contributing scientific models simultaneously accomplished their economic and identity goals, so that having their work categorized as scientific was a means of fulfilling both goals. Tactical media practitioners showed a willingness to be categorized in any way that was helpful to having their political ideas taken up.

Traditional modes of delineating art and science create difficulties for practitioners who do not adhere to these conventions yet hope to win acceptance in and funding from each sphere. On the other hand, eschewing these conventions opens the possibility of drawing on resources from both communities. Some actors explicitly work to create a borderland between art and science. Many bioartists, for example, distinguish between their employment of scientific ideas and techniques and doing science. They claim the former as their work and reject the latter, labeling the outcome of their work *art*. Similarly, some bioartists reject the term *bioart* because it elides art and biology. They claim instead to practice *both* art and biology. The slipperiness of the terms *art* and *science*, as used by these bioartists, undercuts the definitions of what counts as science and at the same time attempts to reinforce the shield that makes artistic practice a thing unto itself.

Tactical media practitioners consciously differ from this way of thinking about the flexibility of categories. Although the Blaschkas understood that a sort of boundary-work, in which they adhered to conventions from both science and artisanal glasswork, was needed to make their models appealing to scientists, tactical media practitioners intentionally work to leverage the categories for their political ends. Tactical media artists discuss and demonstrate that they consider art and science as resources for attracting particular audiences. Both groups interact with boundaries and play on them to garner the right attention for their work. Bioartists, such as those at SymbioticA. similarly invoke political and ethical goals for their work, but they claim to want to maintain the boundary between biology and art, even while creating projects that dissolve that boundary on many levels.

There is no single type of transition or traceable change in how the objects come to fit the definitions of art and science. These two categories continually change as a result of being manipulated by actors for specific purposes around the objects. During my interviews with tactical media artists, some artists stated that calling their work art or science was irrelevant. All that mattered to them was that people were exposed to their ideas, which often related to political issues, particularly critiques of capitalism.

This social difference is created by our system of labeling and categorizing acts of knowledge-making. These categories insist on distinctions, encoding each with power differences that result in structural differences. The hegemony of the sciences has led to and reinforces its own access to capital and government funding, particularly in the United States. These power differences between science and the arts give some actors reason to attempt to position works inside the tent of science. They also perpetuate some of the asymmetries that are observed in art and science collaborations and affect collaborative outcomes. Scientists have access to vastly more public funds than artists do, according to the agencies that serve the two groups. In the US context, the National Science Foundation (NSF) had a 2016 budget of nearly $8 billion, and $8.3 billion by 2020, whereas the National Education Association (NEA) had a 2016 budget of just under $148 million, which grew to only $162 million by 2020. The governmental funding for both groups is instructive. The NSF funds academic science awards, mainly to university-based researchers. The NEA primarily funds arts organizations in the US, which in turn distribute the money. Public art historians, arts management experts, and individual artists often point to a shift in attitudes about funding individual artists that has shaped arts funding over the past thirty years. This change in the way that art funding was distributed was based on Congressional reactions from Republicans, including Jesse Helms and Alfonse D'Amato, during the 1990s, when the NEA came under fire for its support of artists such as Robert Mapplethorpe. The artist's 1989 exhibition *Robert Mapplethorpe: The Perfect Moment* documented the homosexual male bondage, discipline, submission, and masochism (BDSM) subculture of New York City in the late 1960s and early 1970s. The exhibition was deemed obscene by some public officials and sparked a national conversation about constitutionally protected free speech and arts funding. These changes were accompanied by new scrutiny of what should constitute public art. Funding for artists and scientists is of course not provided solely by the federal government: public grants from states and municipalities, private foundations, and university budgets are also important to both groups, so the sources of support are similar in kind, though there again substantive differences in available resources occur.

This financial disparity also has more philosophical implications. Usually the funding disparity is defended as a difference in the economic contributions of science, but even in the face of evidence of economic contributions by the arts, this bias has proved durable. The old adage that if a peace department were created and given the funding of the military, peace might break out everywhere is relevant here. If artists were given the kind of support that scientists have enjoyed in the postwar Big Science era (Galison and Hevly 1992), the arts might be expected to take a similarly respected and transformative role in society. A close look at liminal cases raises the possibility that naturalized differences and their accompanying social roles owe more to the positioning of their makers, champions, and detractors than to an assessment of their practices or outcomes. The thriving interest in art-science work that has grown over the past twenty-five years speaks more to changes in institutional interests and investments of effort and resources to create multidisciplinary projects than to a newly emerging phenomenon. Indeed, the phenomenon is present in all cases when actors work to categorize their efforts and be recognized as producing science, art, or both.

In practice, definitions of art and science are moving targets. They oscillate between the idea that art and science are expressed and symbolized through the objects that they produce, and the idea that art and science are ways of attending to an object, so that the same objects can be subjected to the practices of either domain. Different knowledge networks assign the Blaschkas' work value in different ways. In the case of the Blaschka models, when they were placed in their science context, their curator at Cornell University, Drew Harvell, hoped to garner attention for the cause of marine conservation. Although the Blaschkas certainly imagined scientific uses for their models, they could not have had an inkling of this particular use of enrolling the public in efforts to protect the environment, particularly oceans. Across campus at the Johnson Museum of Art, the models would be treated as examples of craft practices from their particular historical period. Although the Blaschkas talked extensively about their craft, the concept of craft versus art was very much contested by the Arts and Crafts movement of the late nineteenth and early twentieth centuries, led by William Morris, Walter Crane, and T. J. Cobden Sanderson. Though the Arts and Crafts movement looked to raise craft practice above industrial trends, one effect of their socialist art philosophy was the blurring of distinctions between art and craft, which they saw as aesthetically and politically unsound. The easy distinction between art and craft has been further complicated through the recognition that the difference between art and craft was too often the identity status of their makers. In particular, it has been associated with edification of craftwork as a political act related to the elevation of women's craft works to art status. The Johnson Museum of Art has defined art in a way that includes craft, and this is how the Blaschka models are framed in that context.

The fact that the medium of glass as an expected material for craft and fine artworks is also helpful to the museum's curators in setting up a context in which the Blaschka models are a coherent part of the museum's narrative of art history. Although glass has been used for a variety of industrial, technical, and scientific purposes, its long tradition in the arts makes it easier to accept as part of a history of art than, for example, plastic models, which are often included in science center or design collections but are rarely included in art collections. The medium of photography, like glass, has been seen as flexible enough to join the arts, though it also maintains an important standing in science as a method for documenting experiments or providing evidence of direct and indirect observation. Changing definitions of art, that is, its expansion to include some documentary photography, were also necessary for the acceptance of science photographs into art collections. Berenice Abbott's science photographs have only recently begun to be treated as artworks, which has meant that her career has often been understood as divided into an art period and a science period, thereby masking the relationship between her contributions. In the art network, Abbott's relationship to science is understood through her documentary work and realist aesthetic. Many other photographers have worked for scientists, but few have their work included in art collections. The context of Abbott's portraiture and subsequent documentaries certainly plays a role in how her science images are read and their value as artworks.

Conflicts do arise between the use of a network in a project and the project's ability to critique that network. For example, in the case of tactical media practitioners, this played out in the work of the group Preemptive Media in the project *AIR* (2006). *AIR* provided handheld sensors to community members at a variety of urban sites to measure the concentration of pollutants in everyday environments. On one hand, Preemptive Media, like many involved in community-based citizen science projects, wanted to create and spread knowledge about air pollution. This required that they rely on some scientific principles and engineering protocols to create functioning air quality sensors. They also wanted to use their handheld sensors to undermine the scientific standard of stationary sensors and to raise awareness about the flaws in the government's air quality monitoring system. These practitioners employ the technical signs and the scientific language of air quality. They insist on their right to work with materials and to verify ideas that are conventionally understood as inherently scientific, but they do so to challenge the categories they worked within and to reflect on this boundary.

Similarly, the case of the Blaschkas might, on the surface, appear to be what has often been treated in science studies as a typical hegemonic relationship in science: glass artisans serving up their craft for use by scientists. Looking more closely, we find that the Blaschkas contributed to science with their models and that their story reveals an effect of aesthetics in science. The reuse and preservation of these models in art and science contexts shows the high degree of interpretive flexibility that these objects possess. Recontextualizing the models can transform their meaning to viewers. Furthermore, the power of the objects in the art or science contexts may be derived from the power ascribed to the object in the other context. The categories themselves are not blurred. Instead, the practitioner's creation was designed to fit into both networks; it is created to be a liminal object. The tactical media movement of the 1990s did precisely this to serve their political ends. At another level, however, there is an implicit critique of technology's power and ability to be subverted for precisely the types of political maneuvers that these actors regard as necessary to their practice. The bioart movement displays this self-conscious paradox: the actors call themselves artists yet use the techniques and protocols of scientists to create their work. Their work uses and critiques science, yet they insist that it is art.

IDENTITIES AND SKILLS

Two of this book's major themes, identity and skilling, particularly warrant direct comparison here because of their reoccurrence and importance as resources for actors in compelling others to accept work into art and science networks. Seeing these themes across the work of artists engaged with science shows the importance of identity and skilling in situating work. Artists are perpetually involved both as workers in the scientific world and as social critics engaged with society's ideas about science and technology. Artists have long been close to science, allowing for both integration in and reflection on scientific practice.

Identities and skills are intertwined. Self-fashioning through chosen identities and mythologies serves an important role in helping actors position themselves and, thereby, their work. A patriarchal ancestral lineage as glassmakers was the ultimate marker of identity for the Blaschkas, who claimed that their skills were the result of inherited ability. This claim surely fit well with the then-rising scientific tide of the heritability of traits. SymbioticA artists have chosen a lineage that emphasizes both directions of influence between science and art in the persons of Alexis Carrel and Edward Steichen. Tactical media practitioners invent histories and characters to draw attention to their political causes.

Tactical media practitioners sometimes create fictive identities to forward their causes, but the Blaschkas also selected and promoted their identity markers to gain acceptance as observers of the natural world. Although different in kind, these actions are not different in cause. Both engaged the science of their day, if for different purposes. Tactical media artists position themselves ironically and satirically to parody capitalistic control of knowledge, whereas the Blaschkas attempted to extend their representations to meet scientific demands. Bioartists fall somewhere between these two positions. Although they do emphasize aspects of their identities to position themselves as artists or scientists in different contexts, this positioning takes many forms, with different degrees of self-reflexivity. Certainly, intentional fictions are part of the self-fashioning landscape, but more often simple additions and omissions, reflexive or not, shape the way in which objects and information are received. Many contemporary artists, including tactical media practitioners and bioartists, present themselves in costume at performances, though it is hard to draw a line between wearing a lab coat or wearing a power suit to situate one's expertise and simple self-presentation by any public speaker. Sometimes performance or acting skills are utilized as part of their projects, but generally the audience is made aware that they are seeing an act, much as many public presenters are understood to have rehearsed their work in advance. Whether done in a self-reflexive manner or not, identity management plays a crucial role in positioning experts and individuals more generally, so it is no surprise that the actors in these cases work to position themselves, and thereby their work, in relation to the categories of art and science.

Considerable technical skill is required from all the artists in question. Not only did the Blaschkas need to master lampworking and, eventually, the details of creating colored glass, but their model-making also required scientific and technical skills. These skills included observational abilities, scientific drawing, and the ability to emphasize what their scientist-customers would consider the salient features of each organism. Tactical media practitioners also required a host of skills varying by project. These artists require promotional acumen as well as conceptual abilities and, in some instances, acting skills and the ability to create satire or a good joke from the often-serious matters at hand. Many of these artists also need to be familiar with the legal rules that may apply to their work. Additionally, tactical media practitioners need the technical skills to make their websites run, their pigeons with backpacks to fly, and their gels to work. These scientific and engineering skills must then be translated for audiences. Many projects are oriented toward community understanding; these projects then also require skills for working with the public. Bioartists face similar hurdles. They want their scientific projects to translate into ideas for audiences and must shape them to that end.

Bioarts face legal and ethical technicalities as well. In addition to the expertise required to gather the resources to conduct tissue culture or lab work with other living things, bioartists must also navigate the often-complex rules for safety and ethics boards. In addition, they must speak the language of science to fruitfully interact with the scientific community and be familiar with a myriad of lab work protocols. For actors who wish to work at the border of art or science or even undermine their separation, the proper skills are no small matter. They must acquire knowledge valued by both communities. Being recognized as having an eye for observation, a knowledge of equipment, a facility with technical language, or a way with tissue medium helps these artists to work credibly in science and in art. What is it then that these artists are able to create when they use their technical skills to bring audiences an artwork that uses science to critique science?

SEPARATING SCIENCE AND ART IS CONTEXT DEPENDENT

The recognition that the art-science boundary is constructed does not guarantee that the relative power of art and science will be rebalanced. Just as gender has not evaporated under the work of feminist scholars who sought to expose it as a social construction, it is unlikely that any amount of science studies work or number of examples will close the gulf that so many people are working to create between the arts and sciences.

Deconstructing the similarities and differences in specific examples, however, can provide insight into context-specific constructions, as well as the uses of this boundary. This is important work, but like the changes brought about under feminism that were supported by the work of academics but executed by activists, a dedicated group of artists and scientists must work to bring about a more equitable power balance. Just as the STS project that does not consider gender is rare today, ASTS scholars may look forward to a day when art will be considered as a potential subject in every STS study. It is the role of STS to bring science and technology into focus by uncovering the work of its practitioners whether or not they are regularly feted by the science world itself. Given an opportunity, art and studies of art methods may prove their worth as approaches to understanding new aspects of science and technology.

THE MICROSCOPE AND THE PAINTBRUSH

It is typical to associate art and science with different materials. This easy separation, however, is impossible to maintain in the face of the use that bioartists have made of microscopes and the use that scientists have made of artist-rendered representations, images, and models. The separation of types of materials seems to hold up only under the conditions of caricature, and then only in certain contexts. What we know in STS about the way in which scientists employ materials has gone a long way toward undermining the notion that scientists directly read from a material "book of nature." Rather, their interaction is more like the representation associated with classical artists, who are thought to study a subject and then re-present it in another medium.

At the same time, the stereotypes of the artist with a paintbrush and the scientist with a microscope persist for those outside art and science worlds, respectively. Dismissing these ideas as confused public impressions may be to ignore the very sociological factors that are at work here, because people's beliefs about what is or can be science or art may crucially inform those categories' meanings. For example, some artists wear lab coats intentionally to play on the authority vested in the garment, and other artists perform complex experiments in the canonical avant-garde artist garb, all black. Bioartists and tactical media artists make use of expected emblems of science so that as STS scholar Michael Lynch suggested to me, even when they challenge those stereotypes, they reiterate them.

Another point of difference often raised is the divergent training and technical skills thought to be required in the work of each group. As we have seen, however, in the experience of Rudolf Blaschka, this assumption is often contradicted. Rudolf studied natural history and made extensive field trips to collect specimens, along with having training in drawing and lampworking. Many tactical media practitioners and bioartists have backgrounds in science and technical fields. Oron Catts and Ionat Zurr learned tissue culturing directly from Harvard Medical School-based Charles Vacanti, the foremost researcher in the field. Many of the scientists who exhibit images in galleries, for example, the nanoscientists involved in the Materials Research Society's semiannual art competition, have little or no artistic training. They offer up images from their work that are recontextualized as art. It is possible simply to dismiss this competition as amateurish, or even nonart, but the fact that these competitions exist at all raises questions about the way in which images are valued under conditions of recontextualization. Questions were raised, after all, in the early days of bioart about its legitimacy within the artworld, particularly in commercial galleries.

Moreover, there are probably those who would dismiss the training of Catts and Zurr in tissue culture as incomplete, thereby challenging their right to do science because they do not hold scientific degrees. At least among the scientists with whom they share laboratory space, however, there seems to be no disagreement that they are quite capable of performing the scientific practices required to maintain living cells, though not even the actors themselves would call their work science. The idea of scientific training as a distinguishing marker is thereby problematized. Training as a metric for differentiation then presents further ambiguities. With SymbioticA scientists working on art projects and scientists engaging in art competitions, it is not clear how to divide people by using their training.

Another approach would be to examine the institutions that these two knowledge communities have created and work with and through. An institutional point of view might see art and science as differentiated by their relationships to the state. Some artists might like to picture scientists as servants of state power, but, as STS has shown, science and the state have a much more complicated relationship (Wynne 1992; Jasanoff 2004; Mirowski 2011). Artists themselves have a dizzying array of relationships to governmentality and to science as well. Many artists in the tactical media and bioart movements are critical of other artists' relationships to both science and institutional power. In the case of the Wellcome Trust and *The Pig Wings Project*, for example, the bioartists believed that they were being led to take utopic or dystopic positions, implying that genomics was important enough, for better or worse, to warrant all the fuss. The exhibition questions were limited to two-dimensional space in which the primary questions were not the real meaning or value of the genome as the artists saw it, but whether the genome should be under state or private control. In other words, the gallery's question was a recapitulation of many scientists' concerns, rather than an exploration of the genuine reaction of artists. These particular actors believed that it was their role as artists to contest this setup rather than to support one side or the other.

For similar reasons, bioartists also critique those who present images meant to celebrate science and discovery. They see the role of the artist as necessarily involving a reaction to science beyond admiration, though this is hardly a voice in unison. There are dissenters to this vision of the artist as standing against social and political institutions. Communications scholar Fred Turner argues that artists have been enlisted as agents of state power. Turner points to the relationship between Black Mountain artists and the emerging automation of production tasks as executed by American capitalists to suggest that artists are not outside state influence but indeed may act to reframe or even exert pressure on new technologies as they are put into practice (Turner 2006). In *Workshops of Empire* (2015), Eric Bennett showed the relationship between the early Iowa Writers' Workshop and the US government via (among others) the Farfield Foundation, a CIA front for supporting cultural organizations. He suggests that those relationships fostered an ongoing climate of commercially driven creative writing in the United States.

Frances Stonor Saunders has suggested a similar relationship between the CIA-backed Congress for Cultural Freedom and modern art, particularly abstract expressionism (1999, 2013). Given this background, it is perhaps not surprising that different views have emerged among artists on the subject. For example, in light of this history and the arrest of Steve Kurtz, who came under suspicion because of the materials in his home laboratory, artists such as Paul Vanouse are careful to avoid support that might have state linkages of this nature. On the other hand, some artists and art-related groups have been more amenable to these overtures. The intelligence community has been involved in offering opportunities for discussion about safety and regulation and direct support to community biolabs, which often support and work with artists.

In my interviews, I have observed that many artists have a negative reaction to the suggestion that they are science communicators or simply creating beautiful objects from scientific data. This sensibility is built on their collective identity, which demands that they engage in works against state and corporate power. For many, this includes the power that they see vested in modern science. Similarly, the Blaschkas surely would not have tolerated the suggestion that they were creating merely decorative objects. Though beauty is a hallmark of the past and present descriptions of their work, this quality was connected to the idea that they were producing realistic representations of a sublime undersea world. The Blaschkas' style matched the needs of the moment: channeling the marine environment's forms and colors into a recognizable format that orients the viewer and creates a visual language of verisimilitude. Style was required for the models to be interpreted as science. Try as we might to pare these objects down to rational ideas, the nonrational is present as style in colors, forms, and positioning. Here, style is not simply auxiliary. Rather, it is part of what makes a Blaschka model "correct" in terms of contemporary conventions. Styles can make artwork more or less acceptable to the scientific community in a given context. Abbott's documentary-style photos projected a realism that the Physical Science Study Committee believed met their goals for pedagogical images.

In contrast, bioartists employ the apparatus of science styled to express critical ideas. In *Victimless Leather,* dim red lighting gave the bioreactor a mysterious, portentous quality at odds with notions of scientific transparency and objectivity. In this manner, the artists called attention to the fact that white, clean lab aesthetics are themselves a stylistic choice. Kelley (2016) has pointed out the way in which TC&A highlighted that lab aesthetics are active choices with consequences for interpretation. The aesthetics of surgeon and biologist Alexis Carrel's tissue culture lab used entirely gray walls and black floors and furnishings.[4] Oron Catts commented in an interview on the work of Martin Couney at his "infant incubator" facilities in Atlantic City and Coney Island, whose aesthetics were in contrast to the celebrated Alexis Carrel's gray and black world. From 1903 to 1934, premature babies being treated in incubators were accessible to public visits for twenty-five cents. As part of his bid to style the facility less as a sideshow and more as a hospital, Couney insisted that nurses wear starched white uniforms and that doctors wear suits beneath their white coats. The choices made by practitioners in self-styling helps highlight the ubiquitous lab styles, which are often invisible to contemporary viewers because of their prevalence.

All the artists in question emphasize some form of contribution or critique. Bioartists object to characterizations that suggest that their work is auxiliary to science or that it translates scientific subjects for the public. Instead, these artists aim to contribute to debates around and inside science. In contrast, tactical media artists openly state that their goals are political. These agendas are frequently anticorporate, opposing state regulations understood as driven by business interests, or against the science-state complex. Like bioartists, they see their role as artists as necessitating critiques of power. These critiques sometimes require that the actors involve themselves in legal actions, directly interfacing with state power.

The Blaschkas' relationship with power involved their economic concerns and the introduction of style into the scientific objects that they made, because one of their foremost goals was to sell models inside the scientific community. The Blaschkas also wanted to contribute to scientific knowledge, but it was important to them not simply to copy the illustrations of scientists but also to do hands-on observations in their own garden and in the field. They and other artists who worked to contribute directly to the representational culture of science understood themselves not simply as working for scientists but as contributing to scientific knowledge through their observations and by spreading their findings to the community via their models. An account of the Blaschkas that reaches beyond the assumptions that artists are hired and disciplined by scientists to create proper models reveals the contributions that these artists made to creating new and innovative representations to circulate through scientific communities and for use in pedagogical contexts. For the Blaschkas, the role of artisan involved more than serving scientists. They understood themselves to have particular expertise in observation and "tact." They contributed directly to the scientific enterprise by providing the material means for scientific study and by introducing style elements, notably from Art Nouveau and photorealism, into the representation of specimens.

Careful studies of other artists who at present are understood as working for scientists would likely reveal more instances of contributions that go beyond simple commissioning. The Blaschkas were participating in a kind of revolution, however, in making space for themselves as glass artisans in the natural history community. The power to certify their models as part of natural history rested, as it does in all science communities, in the individuals that make up the scientific network. This made constant interaction with researchers and institutions vital to their success. Their agency extended beyond their roles in business and marketing to being contributors in the scientific enterprise.

KNOWLEDGE AND AESTHETICS

Eagleton's understanding of aesthetics as intimately related to the body and yet missed by the Enlightenment gaze is also present in many bioartworks. SymbioticA artists seek to render the uncontrollable quality of corporeal life and lived experience in works such as *Victimless Leather* and concepts such as the aesthetics of care, which challenge assumptions that biology can be predictably and reliably controlled (Catts and Zurr, 2013). Stengers, Catts, and Zurr point out that it is fundamental to science as we know it to subjugate other forms of knowledge, and the resulting omissions risk informing a potentially universal, yet incorrect, impression of what lies beyond its ambit.

These tensions create openings for ASTS as a means of understanding both art's role in terms of science and the value of art as a competing meaning-making system. If the aesthetic is political (the uncontrolled part of society's experiential life), science studies must take it into account when it applies its tools, which are already honed to deal with experience and practice. Amid the rationalist bid to control society's knowledge sphere (to use Stengers's term, 2011), art offers another view of the world according to science and, moreover, a means of critiquing it, albeit in the art community's terms. The difficulty is that to be assessed by science as legitimate, the critique must play by science's rules, which makes impossible external or, indeed, any unauthorized voices.

Nevertheless, artists have managed to use the culture of science (apparatus, language, and subjects) to build very robust critiques. In the case of projects such as *Pig Wings*, for example, these interventions take the form of scientists attempting to harness the work of artists and their access to the public imagination. Expectations of the role of artists in the Enlightenment project is part of the rhetorical posture that scientists often strike in assuring the public that all is well in hand, even in the face of the complexities of working with living things. If science offers the public "what" and science studies offers "how," then art has the potential to offer the unexplainable content of experience.

AESTHETICS IN CONTEXT

Evidence of an actor's identity work may be encoded into a tissue culture artwork or a display of glass sea creatures, yet the power of these objects is usually derived from experiencing them as material arguments. When we experience these arguments, we experience the politics of the aesthetic in Eagleton's terms, the feeling of something outside rational knowledge and its connection to elite values. Attesting to this absence is precisely what motivates many bioartists. It is what they encounter in trying to keep tissue culture pieces alive in the gallery. If we were admiring the accuracy or correctness of their works as science, dozens of other descriptions or configurations of objects would do as well. What we admire is that the messiness has been left in. There is something more there than what is required.

With this in mind, the example of the Blaschka models can be seen in two ways. In one view, they can be interpreted as containing something later recognizable as style. Subjectivity is always present, but in the case of these models, their style did not affect their acceptance as scientific. There was an element of subjectivity in the models that a community of people seeking objectivity tolerated. Perhaps what counted as an accurate model was dependent in part on the Blaschkas' choosing an aesthetic that appeared to be correct in contemporaneous scientific eyes, thereby enabling sales and use by prominent science institutions. Alternatively, the style of the Blaschka models can be seen as so integral to their ability to be interpreted as representations of marine life that we cannot imagine separating the lifelike qualities that the artists imbued in their work from the scientific points that the model buyers were after.

By the same token, Abbott's work can be understood as embodying an artistic perspective that appeared artless to her scientific colleagues but that derived its power from realist aesthetics honed in the worlds of portraiture and documentary. The relationship of the pictorial and the real is present across the cases in this book. I mention it here because of the frequent confusion about the nature of "realistic" depictions in both science and art. The pictorial strain in art, like the Blaschka models, is sometimes recognized as being realistic in science. The fact that a given style is considered realistic by a particular audience, however, or even deemed at a certain time to be acceptable as a means to convey objectivity, is not a sure or stable thing. Both Patricia Piccinini's sculptures and the Blaschka models can fool the eye, particularly in photographs, into believing that something real, rather than representative, is happening. The models are also pictorial in the way in which they purport to resemble real marine specimens, while deploying the conventions of Art Nouveau.

In the case of works such as *Latent Figure Protocol,* the artist is also playing with pictorial possibilities, but in an attempt to wrestle with the meaning of images (in this case from DNA fingerprinting) that science produces. Bioartists create pictorial objects that look like something symbolic (as in *The Pig Wings Project*), but they do not focus on the thing that they actually want to represent—the living cells. In *NoArk II* (Catts and Zurr 2009), the viewer familiar with their work will deduce that the apparatus is a bioreactor of some sort, but the artists are working with materials that cannot be seen in their accompanying apparatus. The care for the cells is made visible through feeding nutrients and temperature gauges. The authenticity of their artistic creations does not come from resembling something real, but from the medium or form through which it is constructed. In this way, bioart might be said to be formalist, because it draws value from its form, though certainly it is not formalist in the sense that all one needs to understand of the work is included in its form.

There are other ways besides the pictorial to understand tactical media or bioart. A project such as *Fish and Chips/MEART* involves creating the materials to support a thought experiment: what if fish neurons could control a robotic arm? What would a fish draw? Here, the emphasis is not on the drawing that the arm creates but on the cyborg configuration of the robotics and the fish neurons. The piece works partly as a philosophical problem and functions like conceptual art, particularly for many viewers who are unable to see the piece in person and experience it primarily as online documentation. The style of the piece is part biotechnology and part Leonardo's workshop. *Fish and Chips* was originally shown at the Ars Electronica's Brucknerhaus in Linz and functioned as a transplanted laboratory. These installed labs provided means and context for such an experiment, where a common feature of early bioart pieces and moving toward or away from these aesthetics remains a tension in exhibition of art in this area.[5] The remaking of labs in cultural spaces deserves further attention in the ongoing conversation in science policy and citizen science about bringing art out of the laboratory and into social space. The interesting effect of carrying the context of technical apparatus into the space is in stark contrast to many contemporary curatorial techniques that make use of white cubes or at least minimal effects. In the current period, bringing the studio into the gallery is a gesture in itself. One effect of rebuilding labs that function more and often less as those in scientific spaces, where works were frequently created, is the way in which this exposes the groups of researchers needed to create such works. This point is important for STS scholars because the remaking of labs in cultural spaces exposes elements of big science as the lone artist genius is sublimated to the obvious logistical and technical complications of many workers and apparatus creators who are rendered visible in recreating laboratories to support or even simply stage such works.

Side by side with a host of experimental apparatuses, understood conventionally as being scientific, *Fish and Chips* or its successor *MEART* might be hard to pick out. Yet it has an aesthetic in Eagleton's sense. Seeing the robotic arm scratch back and forth over a huge sheet of paper, knowing that the arm is controlled by impulses from fish neurons, is an experience qualitatively different from either reading about it or simply imagining such a machine. It might be possible to reduce *Fish and Chips/MEART* to publishable scientific data on neurological impulses, but something else happens in witnessing the robot arm vibrate and scratch across paper. That left-out-something is the aesthetic.

THE FUTURE OF ASTS

The stage is set for fruitful studies of art and science through ASTS. A complete understanding of the power dynamics that have emerged between art and science requires further reckoning. Those who would analyze the dimensions of art and science relations should look to investigate the traditions of protest art focusing on science and technology, science as a power structure ripe for critique, public art as intervention in citizen science, and the role of artists in formulating new ideas to solve science and technology problems, which offer alternatives to other methods and designs. Further work in ASTS will surely call on STS methods and synthesize new methods from art history and visual culture, particularly those that help draw the focus to artists' material practices. ASTS scholars are sure to continue to examine scientists as image makers and the aesthetic modes that they develop for judging their work. Consolidating these studies to consider how those practices intersect with and depart from similar concepts in the art world would provide an interesting comparison. Artists such as the Blaschkas offer an alternative way of thinking about artists as contributors to science, but they might also usefully be compared to other artists working in similar conditions. When I selected this case for study, I hypothesized that the artists identified more closely with the scientific community than the artistic one. It turns out that the Blaschkas derived a large part of their power as skilled glassworkers by emphasizing their artisanal lineage, however.

Another avenue that deserves much more attention is the analysis of art created wholly by scientists, such as those that appear in de Ridder-Vignone's studies of nanoart galleries (2012). This is likely to yield interesting perspectives on how the creators of these artworks position themselves. A study of the situation of science work as art work might reveal how the power of these categories works in enabling the transit of boundaries. Such an analysis would compare interestingly to the science community's acceptance of the *Fish and Chips/MEART* project and its attending scientific publications, an enterprise that emphasized the nature of the experiment and larger philosophical questions related to scientific instrumentation rather than the specifics of individual data points based on the impulses of fish neurons. Such projects also raise questions about the accessibility of this type of art. The concept of *Fish and Chips/MEART* could be reduced to a few sentences of explanation. To fully grasp the work, however, required fairly sophisticated knowledge of how the remotely located chip connects with the drawing arm. In addition to the barriers to understanding the medium and the creative process, considerable contextual information is needed to grasp the piece's cultural critique of the cult of the lone genius. The work did not break science down for uncritical public consumption. Instead, it required the maker and the audience to have the correct pairing of technical skills and social understandings.

Such combinations are often required of STS scholars in different proportions. Conversely, many of the artists treated in this book contributed to scientific projects, shaped public policy/communication, and intervened in politics. I have written elsewhere about the ways in which STS might open the door to science-engaged artists and the ways in which this could benefit science study practices (Rogers 2020). STS communities have hitherto shared scientists' perceptions of artists as under-laborers, yet examining art as a new aspect of STS will surely deepen our understanding of who makes science and how it is made. Our studies may benefit not only by what can be learned about science through artworks or art methods but also from welcoming those who argue through materials rather than through texts.

In art and science, materials and labeling schemes are deeply entangled. The problem of which came first, the material or the language, is intractable. The cyclical production of the definitions of art and science through materials and language, and the inherent reliance on what people say and make to constitute each, mean that neither is ever fully stabilized. Like STS challenging the whiggish history of science, the contemporary art movements examined here challenge visions of art's relationship to science. In turn, these artists offer STS a chance to open new fields of inquiry in the study of knowledge hierarchies.

STS has been a proving ground for the application of feminist, postcolonial, and Marxist ideas. Though power dynamics of erasure and silencing still exist in the practice of science, as they do in STS itself, the ASTS agenda aims to recover skills, knowledge, and contributions. Wearing an ironworking smock rather than a pressed lab coat no longer means that you will be ignored as irrelevant to the scientific project. The contributions of scientists who were women and laboratory assistants, who were frequently women, have been repainted into the scenes of scientific discovery. Once not even a subject in the history of science, nonwestern science and medicine is now a primary focus of STS efforts.

Many ASTS scholars have begun their efforts by observing that scientists and artists are expressly being brought together in increasing numbers for facilitated projects, and the examination of these collaborations can yield a great deal of information about the way in which science and art are categorized today. The emerging dialogues and art-science pairs being directed toward problems best approached in a multidisciplinary fashion offer the possibility for close studies of these collaborations. Some such studies have already been undertaken, and some pairings have been facilitated by STS scholars (Halpern 2014; Calvert and Schyfter 2017). If the arts are to be treated symmetrically with science in understandings of how knowledge is produced, however, ASTS scholars will need to begin to construct analyses beyond this. To study these interactions, scholars will have to resist the temptation to resort to categories already reified in many such collaborations in which assumptions about artists and scientists have created metrics for valid outcomes and measures of success. Such ways of seeing the potential of collaborative projects are ultimately limiting. The capacity of STS to understand how to treat knowledge claims symmetrically can yield a clearer sense of the flexibility of the constructed categories of art and science, even in cases where these roles have been rigidly defined.

Categories are not easy to maintain, but being recognized as part of an art community, science community, or both comes with rewards that can help actors achieve their aims. Whether the categories are sought cynically does not detract from the credit and influence wielded by those who are successful in positioning their work as part of these broader knowledge networks. The cases in this book offer ways of thinking about how we might categorize art-science relations and point the way toward comparative analyses of knowledge categories. Up to now, these relations have been couched in a host of familiar themes: science as a muse for the arts, the arts as a way to communicate and popularize science, the instrumentalization of art for science, aesthetic judgment in science, issues of creativity and imagination within science and art, and science as a subject of protest. Our understanding of these relationships changes when we understand art and science as being categories coproduced by actors for purposes as specific as their contexts: to position work as authoritative, to make science accessible to particular publics, and to offer social and political critiques. Attention to the construction of art and science and their constitutive areas of knowledge reveals commonalities and frees us from inaccurate divisions so that we may better understand knowledge-making and its accompanying meanings.

NOTES

PREFACE

1. See, for example, Ian Berry, ed., *Paradise Now: Picturing the Genetic Revolution* (2001), Lucy R. Lippard, Stephanie Smith, and Andrew Revkin, *Weather Report: Art and Climate Change* (2007), Guy Abrahams, Bronwyn Johnson, and Kelly Gellatly, *Art + Climate=Change* (2016), and Hannah Star Rogers, ed., *Art's Work in the Age of Biotechnology: Shaping Our Genetic Futures* (2019).

2. For a compilation of organizations working in this area and their leadership, see Clay, Rut, and Senior (2015).

3. In *Making Art Work* (McCray 2020), W. Patrick McCray articulated the Cold War context of Frank Malina, the pioneering U.S. engineer-artist who founded the journal Leonardo in Paris in 1968. Malina co-founded what would become the Jet Propulsion Laboratory in Pasadena in 1936 and Aerojet Engineering, America's first rocket engine manufacturer, in 1942, before he grew disillusioned with McCarthyism and the militarization of rocketry in the 1950s and moved to France.

4. The final report, *The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education: Branches from the Same Tree*, was issued in 2018 and is accessible from the National Academy of Sciences website: https://www.nationalacademies.org/our-work/the-integration-of-the-humanities-and-arts-with-sciences-engineering-and-medicine-in-higher-education#sectionPublications.

5. This indeterminacy complicates potential alliances with funding bodies. Even as efforts to understand the effects of art-science are ongoing, its meaning remains contested.

CHAPTER 1

1. Chris Salter (2010) argued that the co-development of technology and art, especially in the space of innovation in the performing and visual arts, should be understood as having many historical links and a more interrelated process of development than is generally understood.

2. Stirling's claims about the problems of oversimplification were pointed out to me by communications and composition scholar Elizabeth Pitts.

3. The construction and use of the term technology is particularly central in projects of Critical Art Ensemble, subRosa, and Mark Shepard. The Ars Electronica community has laid the foundation for how many artists and others define what art and technology might look like. The changing definitions of technology remain important in how practitioners in that community define their artwork, which is often clustered are the use of a specific piece of hard or software as opposed to an aesthetic drive. Similarly, the idea of art and engineering has been central to academic programs, such as Arizona State University's Arts, Media, and Engineering program and the short-lived but important Arts, Computation, and Engineering (ACE) graduate program (2003–2011) at the University of California at Irvine, as well as being an important touchstone in the careers of Natalie Jeremijenko, Beatriz da Costa, and Brooke Singer.

4. As Barry Barnes has pointed out to me, reification like deconstruction is as complex as it is unavoidable and this situation is not entirely regretable as it leads to community. The literature of finitism is a good source of further justifications for constructivism. Constructivists should not regret having to reify 'science' and 'art' as our aims are to identify them as social constructions. Reification cannot be avoided as it is crucial to language and communication, as not even those most adroit at deconstruction manage to avoid it. In a world of diverse things and processes, every one of which is both similar to and different from every other, communication needs constructed classifications, which are continually selected, supported, and deconstructed. Reification is at least as important as deconstruction as these constructs build collective understanding. This means that possessors of language must be seen as at once constructors, modifiers, and destroyers of the orders they inhabit. This is, in fact, an ordinary condition. Anyone may act: to reify or deconstruct and to wrap ideas in layer after layer of rationalisations which authorise, diminish, and complicate constructs.

CHAPTER 2

1. A helpful interactive map indicating where the Blaschka models were sold and where they are currently housed worldwide was created by the Corning Museum of Glass in Corning, New York (https://dm.cmog.org/blaschka/).

2. Since the time of this writing, the Blaschka glass models at Cornell University were significantly restored under the direction of curator Drew Harvell. The models were relocated for a major exhibition at the Corning Museum of Glass and at the Albert R. Mann Library and are now back on display following their conservation and a redesign of the displays in Corson Mudd Hall.

3. Drew Harvell, personal communication, 2010.

4. Reviewers praised the color lithographs made from Gosse's watercolors. The *Literary Gazette* of April 7, 1860, noted Gosse's artistic and scientific acumen as "alone and unrivalled in the extremely difficult art of drawing objects of zoology so as to satisfy the requirements of science" while providing "vivid aesthetic impressions" (Thwaite 2002).

5. For more on Haeckel's visual arguments for Darwinian theories, see Halpern and Rogers (2013).

6. During the major model restoration at Cornell led by Drew Harvell, the black background was used as a standard in photographing the objects for digitization, so that most images of the Cornell models can be compared with the same background conditions.

CHAPTER 3

1. I regret that I have been unable to reproduce Abbott's photographs for the reader owing to the costs of securing the right to reproduce them. I believe that artwork is realized through experience and engagement. It is a special irony that these images are unavailable given the stated wish of the photographer to make science accessible. Artists should always be the beneficiaries of their labor, and our current situation often gives them or their heirs few benefits while further consolidating art, like capitol, in the hands of a few.

2. It is this form of inquiry, the attempt to analyze the possible interpretation of the object, that is one clear form of the way in which curator's practices are forms of knowledge making. In the same way that STS scholars primary interviews and archival reconstructions of how others' have made sense, curators create new knowledge around objects by analyzing the layers of meaning added to them in different context. This process is not dissimilar from the STS analyst approaching a technical artifact with the Bjker and Pinch's SCOT method.

3. It is interesting that Abbott credits both men, because their aims were rather different. Man Ray invented the Rayogram as part of his investigation of surrealism and the human mind, whereas Moholy-Nagy was experimenting with the physics of art.

4. For an overview of Berenice Abbott's photographic and textual collaboration with Muriel Rukeyser's "So Easy to See," see Kennedy-Epstein (2019).

5. Bubbles are more readily formed in soft than hard water because hard water contains calcium, which creates a polarity that interferes with bubble formation, interrupting the action of soap. Soaps contain polar and nonpolar molecules, which act as a bridge to bound water to lipids, such as fat or grease.

6. Elsewhere I have written with Megan Halpern about the way in which different artworks can offer affordances for different types of science communication efforts that stretch beyond communicating information to engagement efforts around context and contested science. See Halpern and Rogers (2022).

CHAPTER 4

1. The BLO documented its press coverage in a short film entitled Operation New-Speak, which included footage and participants as well as newsclips presented to the resulting press. In addition to media outlets, the intervention was referenced in an episode of The Simpsons and in a Jay Leno monologue on The Tonight Show; see http://sniggle.net/barbie.php.

2. These include *The Electronic Disturbance* (1994), *Electronic Civil Disobedience & Other Unpopular Ideas* (1996), *Flesh Machine: Cyborgs, Designer Babies, Eugenic Consciousness* (1998), *Digital Resistance: Explorations in Tactical Media* (2001), *Molecular Invasion* (2006), and *Marching Plague* (2012).

3. The story of Kurtz's work and arrest inspired the film *Strange Culture* (2007) by documentarian Lynn Hershman Leeson. Major features of the story inspired Richard Power's novel *Orfeo* (2014).

4. Manjari Mahajan observed that she encountered a similar phenomenon with a nongovernmental "organization" in India that opposed GMOs, whicht turned out to be a single resourceful activist.

5. Mark Shepard, interview with the author, September 8, 2007.

6. Natalie Jeremijenko, interview with the author, September 25, 2007.

7. Paul Vanouse, interview with the author, July 28, 2007.

8. Igor Vamos, interview with the author, August 10, 2007.

CHAPTER 5

1. It is worthwhile to note here the distinction between SymbioticA and the Tissue Culture and Art Project (TC&A). SymbioticA is a Centre of Excellence in Biological Arts within the School of Human Sciences at University of Western Australia and hosts a very wide range of artists and researchers, among whom were founders Oron Catts and Ionat Zurr. These two artists practice their own art as The Tissue Culture and Art Project (TC&A). TC&A is "hosted" within SymbioticA, but SymbioticA refers to the broader institution and activities of many visitors, residents, and other ongoing art-science ventures.

2. Note how this statement resonates with the thesis of Evelyn Fox Keller's "Feeling for the Organism" (1983).

3. This follows well from the distinction made by Born and Barry (2010) that many practitioners in the field of what they term current art-science are making a radical departure from the idea that they are communicating a complete science and are working instead to form a "public experiment," which by its nature insists on an incompleteness and allows artistic researchers to enter into the same questions as scientists from new perspectives, a platform from which they are potentially contributing to knowledge making.

CHAPTER 6

1. For more on how art-science curators make arguments, see the author's exhibition-related publications: "Curating art and science: Art's work in the age of biotechnology" (Rogers 2019); "Curating art, science, and technology" (Rogers 2018a); "Shadows and ashes: The peril of nuclear weapons" (Rogers 2018b); "Intersecting art and science: Curation, curriculum, and collaboration" (Rogers 2017b); and "Art's work in the age of biotechnology: Shaping our genetic futures" (Rogers 2017b).

2. Zurr gave this explanation which connects tissue culture to Evelyn Fox Keller's book on cytogenetist and Nobel Prize winner Barbara McClintok, A Feeling for the Organism (1984) in her undergraduate course on bioart at the University of Western Australia in 2007. Zurr demonstrates once again the degree of crossover between educators, facilitators, theorists, and rpactioners in the area of art and science. The history of the field of ASTS has been occluded to a degree by disciplining and categorization around STS and art-science, which leads many STS scholars working in this area to formally divide their roles as analysts from their roles as curators and facilitators. There are a number of STS-trained practitioners with a professional interest in the arts who have worked as art-science facilitators or curators including Bruno Latour, Peter Weibel, Christopher Salter, Ruth Benschop, and Regula Valerie Burri. My own work in this field developed in relation to an emerging community of ASTS practitioners including Bilge Hasdemir, Dehlia Hannah, Silvia Casini, Nora S. Vaage, Megan K. Halpern, Jane Calvert, Lea Schick, and Kathryn Vignone-de Ridder. Another notable feature of these interactions is the frequency with which they also resulted in publications authored by STS scholars in combination with artists. For a recent example, see Szymanski et al. 2020.

3. The exhibition continued in 2021 at the University of Pittsburgh in collaboration with Elizabeth Pitts under the title Art's Work in the Age of Biotechnology: Critical Methods for Collective Experiments. This new assemblage of works and responses placed further emphasis on creating layers of content around a fresh set of artworks connected with issues of race, gender, and non-humans.

4. Panels included Biotechnology as Culture (moderated by Priscilla Wald; panelists: Joe Davis, Jennifer Willet, Ciara Redmond, Kirsten Stolle, Maria McKinney, and Rich Pell); Genetic Arts Intervening in the Anthropocene: Climate, Geoengineering, and Ecosystems (moderated by Jason Delborne; panelists: Aaron Ellison, David Buckley Borden, Jon Davis, Joel Ong, Erin Kirchner, and Rachel Rusk) and Art and Identities: From Surveillance and Privacy to Collective Identities and Personal Choices (moderator: Patsy Sibley; panelists: Charlotte Jarvis, Paul Vanouse, Adam Zaretsky, and Emeka Ikebude).

5. Field Trial repurposed the pop-up exhibit as a knowledge-making event supporting the construction of the main exhibition. Pop-up exhibits have largely emerged as a way to deal with the expense of a long-term exhibition, particularly in places where rental costs exceed the means of most artists. Pop-up exhibitions tend to combine the feeling of an installation visit with an arts event. One of the effects

of a pop-up exhibit is a further emphasis on documentation, such that most viewers experience the artwork through images and video rather than at the short-term exhibition. The situation of wanting to encourage social media users to widely broadcast documentation of the artwork encourages art world professionals to locate pop-up exhibits in places with a high volume of foot traffic and in locations that contextualize the art in a way that is "selfie ready." These experts often select physical contexts for the artworks that contrast with or heighten the works, rendering them easy to photograph in aesthetic, attractive, or fun ways. Our goals in creating the Field Trial pop-up exhibit were different in that our intention was to test potential artworks and offer a draft experience to the public and symposium contributors to which they might respond to shape the final exhibition.

6. I am indebted to artists and operatic scholars Michael Klein and Roman Lemberg for conversations on this point.

7. For more on critical approaches to improving Ethical, Legal, and Social Implications Research Program frameworks, see Balmer et al. (2016). For more on best practices in Rights and Resources Initiative contexts, see The ERA CoBioTech strategic agenda, which is published as a joint effort between the partners of the European Research Area Network Cofund for Biotechnologies (ERA CoBioTech). This framework was developed by Robert Smith, Deborah Scott, Thoko Kamwendo and Jane Calvert (Science, Technology & Innovation Studies, School of Social & Political Science, University of Edinburgh) in March 2019.

8. This work was a precursor to Agapakis's well-received collaboration with Sisel Tolas and Alexandra Daisy Ginsberg Resurrecting the Sublime (2019).

9. Like many works in the life sciences and art that use live animals, McKinney directly addresses ethics and the use of animals in art as part of her work.

10. In a 2015 article on bioart in Trends in Biotechnology, Yetisen et al. note that though Steichen would go on to work with colochine and delphiniums—creating Carl Sandberg in 1938 and the well-known Connecticut Yankee in 1960—those shown in the Museum of Modern Art in 1936 were not acheived using colchine because the first publication about using colchine on plant materials did not appear until 1937 (Blakeslee and Avery). This point was helpfully suggested to me by Joe Davis, who coauthored the article and whose work appeared in the Art's Work in the Age of Biotechnology exhibition. Indeed, the press release for the exhibition describes the delphiniums as "a new American strain which after twenty-six years of cross-breeding and selection by Mr. Steichen" are being exhibited to the public for the first time. Materials from Steichen's delphinium project are catalogued at the Museum of Modern Art archive. I found no evidence to contradict Yetisen's claim that colchicine was used by Steichen until after the 1936 exhibition.

11. The artist's own work seems to have sought to undermine the suggestion of this one-to-one correspondence with further works on probability in pieces like *Probably Chelsea* (2017).

CONCLUSION

1. Crossing Kingdoms was included in Art's Work in the Age of Biotechnology: Critical Methods for Collective Experiments at the University of Pittsburgh in 2021.

2. Artist Tarsh Bates is a noted expert on working with yeasts. For more on Bates's interspecies work, see T. Bates, "Performance, bioscience, care: Exploring interspecies alterity," *International Journal of Performance and Digital Media* 10 (2) (2014): 216–231.

3. The experiment attempted to fuse yeast cells with human embryonic kidney cells using a protein derived from a snake virus.

4. *Tissue Culture & Art* critiqued Alexis Carrel's eugenicist positions and suggested the way in which such positions remain entangled in current biotechnologies.

5. This item was helpfully pointed out to me by an anonymous peer reviewer.

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